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MARBLE RESOURCES OF SOUTHEASTERN ALASKA

BY

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WITH A SECTION ON

THE GEOGRAPHY AND GEOLOGY

BY

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By Alfred H. Brooks.

Alaska marble was first used, long before the coming of the white man, by the natives, who carved utensils and ornaments from some of the more highly colored varieties. The Russian occupants of Alaska gave no heed to the marble, though they may have utilized a few slabs for tombstones. The marbles of southeastern Alaska were among the first of the mineral deposits of the Territory to be mentioned in the official reports of the United States Government. For many years these marbles excited no interest, for in spite of their favorable location on tidewater there was no market for them and accordingly they had no value. Probably some time in the early nineties a little marble was quarried on Ham Island, in the Wrangell district, and worked up into tombstones, which were sold at localities near by. These tombstones were in considerable demand among the natives, who learned their use from the white man and substituted them for the crudely carved wooden totems.

It was about 1896 that the first thought was given to opening the Alaska marble deposits on a commercial scale, for by this time the rapid growth of the cities of the west coast had made a demand for ornamental and building stone. After some years of prospecting on the deposits on the northwest side of Prince of Wales Island, a quarry was opened near Calder, and shipments were begun in 1902. Since 1904 there has been a steady increase in the marble output of Alaska, which, however, has practically all come from a few quarries in the Shakan-Calder region of the Ketchikan district. Although, as this report shows, marble is widely distributed in southeastern Alaska, its development has thus far been limited to one general region.

Previous to Mr. Burchard's investigation of the marbles of southeastern Alaska they had received only scant attention by the Geological Survey. A few of the marble deposits had been visited by geologists, but the examinations were only cursory and incidental to the study of other problems relating to geology and mineral resources. Mr. Burchard deserves great credit for having procured in two short field seasons so large an amount of data relating to the marbles of this region. He has been able to indicate in a general way the areas containing marble deposits. Detailed information regarding the distribution and extent of the deposits will be possible only after complete areal and structural surveys have been made. This work will be undertaken as soon as circumstances permit. Meanwhile this report will serve a valuable purpose in presenting a complete statement of present knowledge concerning this valuable mineral resource of the Territory.

MARBLE RESOURCES OF SOUTHEASTERN ALASKA.

By Ernest F. Burchard.

INVESTIGATIONS.

Studies of the marbles and other structural materials of southeastern Alaska were made for the United States Geological Survey by F. E. and C. W. Wright in 1904, 1905, and 1906, and the results were published in Survey bulletins.[1] Between 1908 and 1912 nothing was added to the reports on the subject.

In the autumn of 1912 the writer made an examination of the marble areas on Prince of Wales, Kosciusko, Marble, Orr, Tuxekan, Heceta, Ham, and Revillagigedo islands, and in the autumn of 1913 this work was extended to deposits on the mainland bordering Blake Channel, Stephens Passage, and Glacier Bay, on several islands in Glacier Bay, and on Chichagof and Admiralty islands. About nine weeks in all was spent in the field work of the two seasons, which involved cruising along about 1,500 miles of shore line in small gasoline launches. The results of the work completed in 1912 [2] and notes concerning the deposits examined in 1913 lying north of Frederick Sound [3] were published in Survey bulletins. The field seasons of 1915 and 1916 were spent by Theodore Chapin in geologic work in southeastern Alaska, and he gathered additional notes concerning marble deposits on Dall, Long, and Revillagigedo islands. The more important of these deposits have been described by Chapin.[4] Practically all the available data on marble deposits in southeastern Alaska have been brought together in the present bulletin.

The manuscript for this bulletin was submitted in October, 1916, but owing to the large number of publications which were expedited

[1] Wright, F. E. and C. W., Economic developments in southern Alaska: U. S. Geol. Survey Bull. 259, p. 68, 1905; The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull, 347, pp 191–198, 1908. Wright, C. W., Nonmetallic deposits of southeastern Alaska: U. S. Geol. Survey Bull. 284, pp. 55–57, 1906; A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, p. 154, 1906; Nonmetalliferous mineral resources of southeastern Alaska: U. S. Geol. Survey Bull. 314, pp. 73–77, 1907; The building stones and materials of southeastern Alaska: U. S. Geol. Survey Bull. 345, pp. 116–122, 1908.

[2] Burchard, E. F., Marble resources of Ketchikan and Wrangell districts: U. S. Geol. Survey Bull. 542, pp. 52–77, 1913.

[3] Burchard, E. F., Marble resources of Juneau, Skagway, and Sitka districts, Alaska: U. S. Geol. Survey Bull. 592, pp. 95–107, 1914.

[4] Chapin, Theodore, Mining developments in southeastern Alaska: U. S. Geol. Survey Bull. 642, pp. 100–104, 1916.

on account of the European war, coupled with a shortage of draftsmen, the preparation of the illustrations for the printer was of necessity deferred until the summer of 1919.

The petrologic character of the intrusive and metamorphic rocks associated with the marble deposits was determined by J. B. Mertie, and petrologic studies of many of the marbles in thin sections were made by T. N. Dale and G. F. Loughlin, of the United States Geological Survey.

The Survey herewith expresses its appreciation of the cordial treatment extended to its representatives by Mr. F. E. Bronson, collector of customs at Wrangell; the Vermont Marble Co., the Mission Marble Works (later the Mission-Alaska Quarry Co.), the Alaska Marble Co., the El Capitan Marble Co., the Alaska-Shamrock Marble Co., Messrs. Woodbridge & Lowery, Frank Spalding, Walter C. Waters, M. D. Ickis, and many others interested in the development of the marble resources of southeastern Alaska.

GEOGRAPHY AND GEOLOGY.

By Theodore Chapin.

GEOGRAPHY.

LOCATION AND EXTENT.

The region popularly known as southeastern Alaska comprises the panhandle extending from Dixon Entrance northwestward to Mount St. Elias. It is bounded on the northeast by British Columbia and Yukon Territory and on the southwest by the Pacific Ocean, forming a strip 400 miles long and 100 to 150 miles wide, with a narrow extension on the northwest 100 miles long and 25 to 50 miles wide. That portion concerned in the present sketch, as shown on the index map (Pl. I), extends southeastward from Mount Fairweather. It comprises a mainland belt and a bordering group of islands known as Alexander Archipelago. The larger islands forming this group, named in order from north to south, are Admiralty, Chichagof, Baranof, Kupreanof, Kuiu, Revillagigedo, Prince of Wales, and Dall islands. Other smaller islands important on account of their deposits of marble are Ham, Long, Kosciusko, Marble, and Orr islands.

RELIEF AND DRAINAGE.

Southeastern Alaska is a very mountainous region, lying within the Pacific Mountain system, which as defined by Brooks[1] includes a broad zone of ranges parallel to the southern coast of Alaska. In southeastern Alaska the dominant feature of this province is the

[1] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 14, 1902.

Coast Range, a rugged mountain mass extending along the northeastern boundary for its entire length. The Alexander Archipelago is made up of a mountain mass composed of a number of ranges not sharply differentiated from the Coast Range and sometimes regarded as a southeastern extension of the St. Elias Range.[1] The entire region gives the impression of a high plateau deeply dissected by erosion. It is veined by an intricate system of waterways; the islands are separated from the mainland and from one another by deep channels from which fiords penetrate both islands and the mainland, making a very sinuous coast line and numerous inlets and bays.

The region is one of marked relief and very rugged topography. The land rises abruptly and in many places precipitously from the water's edge, reaching altitudes of several thousand feet a short distance from the shore.

The four main rivers of southeastern Alaska, the Alsek, Chilcat, Taku, and Stikine, rise in British Columbia and flow across the coast ranges to the sea. The islands are drained by small streams.

GLACIATION.

Southeastern Alaska shows unmistakable evidence of very general glaciation which affected all but the highest parts of the region and produced a characteristic topography. Among the many features of glacial erosion that are developed to a remarkable degree the most conspicuous are the interdigitating fiords that penetrate the entire region. The most prominent of these fiords is Lynn Canal, which with its extension, Chatham Strait, forms a nearly straight channel for over 220 miles. Portland Canal, another remarkable fiord, is about 100 miles in length. Other marks of glacial sculpture are the cirque basins, hanging valleys, U-shaped valleys, polished and grooved surfaces, and lakes with rock-rimmed basins deepened by glacial scour. Glacial deposits are uncommon except in the vicinity of the present glaciers, although erratic boulders occur in places.

Glaciers occur on the mountain slopes of the mainland, and at least one small one has been observed on Admiralty Island. North of Stikine River many of the glaciers reach the sea and discharge ice into the fiords and bays.

CLIMATE.

The climate of southeastern Alaska is characterized by moderate temperature and abundant precipitation. The winters are comparatively mild, and the ports are open to navigation the year round. Near sea level the first frosts occur about September or October

[1] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 29, 1906.

great favor for airplane construction and is used in England and France, as well as in the United States.

The red cedar is used for shingles and for boat timber. The yellow cedar also is used in boat construction and is suitable for furniture and pattern making, but it is not easily obtained, as little of it grows below an altitude of 500 feet above sea level.

Among other trees common to this region may be noted mountain ash, cottonwood, quaking aspen, crabapple, willow, and alder. From sea level to an altitude of 1,500 feet or so the forests contain a dense undergrowth of berry bushes and other shrubs that form in places an impassable barrier, through which trails must be cut. The most objectionable of these shrubs is the devil's club, a luxuriant bush whose stalks and stems are thickly covered with sharp, fine thorns. Salmonberries are the most abundant and form impenetrable thickets. Huckleberries are plentiful; they include two varieties of blue and one of red berries. The region also contains high-bush cranberries and black currants.

POPULATION AND SETTLEMENTS.

The population of southeastern Alaska is distributed mainly among the mining and fishing centers. Skagway, the northernmost town, is the terminus of the White Pass Railway. Juneau, the Territorial capital, is the distributing center of the north end of southeastern Alaska. Four miles southeast of Juneau is the new town of Thane, and across Gastineau Channel is the town of Douglas, maintained principally by the operations of the Treadwell mine. Sitka, on the west coast of Baranof Island, is the home of the agricultural experiment station and a general supply point. It is of special historic interest as the first capital of Alaska and contains valuable relics of the early Russian occupation. Wrangell and Petersburg are supply centers for the central part of the region and outfitting stations for expeditions up Stikine River. The southern part of the region is served by Ketchikan, the first port of entry in southeastern Alaska and headquarters of the Forest Service. There are also scores of small settlements at or near canneries or mines, to which regular mail and passenger service is maintained and where boat supplies, fuel, food, and clothing can be purchased. Gasoline launches and boats may be hired at any of the larger towns. Freight rates are reasonable, and costs compare favorably with those at Seattle.

ACCESSIBILITY.

Transportation facilities on land are poorly developed. The rugged nature of the land, with its many swampy areas and the heavy growth of brush, as well as the numerous deep fiords and channels that cut into or separate the islands, precludes the possibility of the extensive construction of railroads, or even of wagon roads, except at unwarranted expense. The need of railroad construction is in large part obviated, however, by the intricate system of waterways which penetrates the entire region, providing excellent highways for deep-sea vessels and numerous deep-water harbors in sheltered bays. Many marble deposits occur near tidewater and on sheltered bays; at less favorable localities the construction of surface or aerial trams is facilitated by a supply of suitable timber near by.

GEOLOGY.

GENERAL FEATURES.

The study of the geology of southeastern Alaska, though not sufficient in detail to admit of accurate mapping, has established certain geologic relations and a general sequence of rock types that is more or less uniform throughout the region. [1]

The rocks of this region comprise a variety of both sedimentary and igneous types and their metamorphic derivatives. In age they range from early Paleozoic to Recent. The details of their structural and stratigraphic relations are complex. The older rocks are closely folded and for the most part are disposed in zones whose axes strike about northwest, approximately parallel to the trend of the Coast Range. This system of folding, however, is complicated by an older system, and the combination of the two tends to throw the beds into complex structural relations. The stratigraphic and structural relations are further complicated by overturned folds. With the exception of the more recent formations most of the rocks are more or less metamorphosed, so that their original nature is in large part obscured.

SEDIMENTARY ROCKS.

The Paleozoic rocks, which are grouped and shown with one pattern on the accompanying index map, comprise a number of separate formations that include a great variety of sediments. They may be grouped roughly in two major divisions separated by a marked

[1] The writer has drawn freely from the following published Survey reports concerning parts of the region with which he is not familiar:

Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, 1902; The geographic and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, 1906.

Spencer, A. C., The Juneau gold belt; Wright, C. W., A reconnaissance of Admiralty Island, Alaska: U. S. Geol. Survey Bull. 287, 1906.

Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, 1908.

Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, 1911; The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, 1912; The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, 1912.

Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95 pp. 97–105, 1915.

unconformity and differing considerably in amount of metamorphism. The older of these divisions, which probably includes a number of formations, is pre-Devonian. The younger division is Devonian and Carboniferous. The older Paleozoic rocks crop out at several places on Dall, Prince of Wales, Baranof, Chichagof, and Kuiu islands, and along Glacier Bay on the mainland. In the Ketchikan district the oldest Paleozoic rocks may be divided into three conformable terranes, of which one is prevailingly arenaceous, one calcareous, and one tuffaceous. These distinctions, however, are only general, for limestone beds occur throughout the series and thin sheets of tuff are intercalated with all other members of the series.

Unconformably overlying this lower series is a succession of tuffaceous conglomerate and grits, black and green slate, and limestone, with intercalated lava flows and breccias, which probably belong to the older Paleozoic division. These older Paleozoic rocks contain Silurian fossils at a number of places, and in the Ketchikan region they are overlain unconformably by Lower and Middle Devonian rocks. It is thus evident that they are Silurian, and possibly older.

Overlying the older Paleozoic rocks with apparent unconformity are massive conglomerates and arenaceous sediments interbedded with and overlain by gray massive limestone of Lower and Middle Devonian age. The Upper Devonian rocks consist of dark-colored limestones and black cherts associated with basaltic flows and breccias. The Devonian rocks have a wide distribution and have been found on Hotspur Island, a small island near the southern point of southeastern Alaska, on Gravina Island, at various places on Prince of Wales Island, and the small islands off the west coast, and on Chichagof Island.

Carboniferous rocks also are widely distributed in southeastern Alaska and include limestones representing three horizons, one Mississippian and two Pennsylvanian. The lower Carboniferous beds are composed of interbedded limestone and black chert and are very similar in appearance to the Upper Devonian beds, which they appear to overlie conformably. The upper Carboniferous formations are gray to white heavy-bedded massive limestone. Presumably still higher in the Carboniferous section are phyllites and greenstones with beds of dolomitic limestone.

The workable deposits of marble appear to be confined to the Paleozoic limestone beds. The older Paleozoic limestones are all more or less metamorphosed and in places are entirely recrystallized. The Devonian and Carboniferous beds are less metamorphosed and except in the vicinity of intrusive rocks are less crystalline. Some of the best marble deposits, however, occur in the younger Paleozoic limestones, which are in close proximity to granitic intrusives. The formation of the marble thus appears to be due more to contact metatexture. The chief agents that bring about these changes are pressure, heat, and chemical action, generally at considerable depths below the surface of the earth. By metamorphic agencies limestone is transformed into marble. During the transformation the original bedding of the limestone may become nearly or completely obscured, and the crystalline texture and folded structure characteristic of marble are induced.

ORIGIN OF LIMESTONE.

The sediments that now constitute sedimentary rocks were deposited under water in estuaries, seas, and lakes, on land surfaces, and in cavities and crevices in other rocks. The chief agent in the transportation of rock débris is water in motion, including rain water, streams, currents, and waves. Considerable débris is transported by moving ice in the form of glaciers and icebergs, and small quantities of very fine, light material are carried by the wind. Deposits of material carried as solid particles are said to be mechanical. Deposits formed largely of the remains of organisms are called organic; such deposits include some formed by deposition from solution. Material precipitated from solution without the aid of organisms forms chemical deposits.

Calcium carbonate ($CaCO_3$), the principal compound in limestone, is slightly soluble in pure water, 1 liter of pure water solution at 8.7° C. containing 0.01 gram of the compound.[1] In water charged with carbon dioxide (CO_2), forming a solution of carbonic acid, calcium carbonate is more soluble and forms calcium bicarbonate. The reactions are as follows:

$$\underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2} \rightarrow \underset{\text{Carbonic acid}}{H_2CO_3}$$

$$\underset{\text{Carbonic acid}}{H_2CO_3} + \underset{\text{Calcium carbonate}}{CaCO_3} \rightarrow \underset{\text{Calcium bicarbonate}}{CaH_2(CO_3)_2}$$

One liter of water saturated with carbon dioxide contains at 15° C. and zero partial pressure of carbon dioxide 0.385 gram of calcium bicarbonate.[2] Under natural conditions a less quantity is dissolved, but it is believed that under such pressures as exist at considerable depths below the surface of the earth water will dissolve still greater quantities. Water sinking through the soil meets and dissolves carbon dioxide, which is constantly being given off from decaying vegetable matter. This acidulated water then takes up calcium carbonate from the soil and from the rocks through which it percolates. The water of streams is therefore constantly bringing a supply of dissolved calcium carbonate to the ocean. Evaporation

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[1] Seidell, Atherton, Solubilities of inorganic and organic substances, p. 86, New York, D. Van Nostrand Co., 1907.

[2] Idem, p. 87.

tends to concentrate this material in sea water, and were it not for the fact that large quantities of calcium carbonate are constantly being removed through the agency of marine organisms the sea water would become overcharged with this salt. Sea water contains about 34.40 parts to the thousand, by weight, of mineral matter in solution. The proportions of the principal solids are shown in the following table:

Percentages of mineral salts in total solids contained in sea water.[1]

Sodium chloride ($NaCl$)	77.758
Magnesium chloride ($MgCl$)	10.878
Magnesium sulphate ($MgSO_4$)	4.737
Calcium sulphate ($CaSO_4$)	3.600
Potassium sulphate (K_2SO_4)	2.465
Magnesium bromide ($MgBr$)	.217
Calcium carbonate ($CaCO_3$)	.345
	100.000

Gases are also present in sea water, including a relatively large quantity of carbon dioxide, and these tend to increase the solvent power of the water on calcium carbonate.

There is no sharp line of distinction between chemical and organic deposits. Organic deposits are really chemical in the broader sense, but they are termed organic because their precipitation is immediately dependent upon living organisms. Subaqueous inorganic chemical deposits are probably formed mostly in shallow water and include those due to the evaporation of the water and those due to chemical reactions between solutions, resulting in the precipitation of new and insoluble compounds.

Chemical deposits formed in shallow water are chiefly simple precipitates resulting from evaporation. All substances in solution are necessarily precipitated upon complete evaporation of the solvent, but as sea water is rarely saturated with its most abundant salts only a few are precipitated in quantities sufficient to be of geologic significance. The principal deposits formed on incomplete evaporation that are of interest in the present connection are calcium carbonate ($CaCO_3$, limestone), calcium sulphate ($CaSO_4.2H_2O$, gypsum), sodium chloride ($NaCl$, rock salt), and chlorides and sulphates of potassium and magnesium.

The deposits of calcium carbonate, including shells and coral, have been very much greater than those of calcium sulphate, because marine plants and animals extract calcium carbonate and not calcium sulphate from the sea water for their skeletons and shells, although the water contains more than ten times as much calcium sulphate as

[1] Dittmar, William, *Challenger* Rept., Physics and chemistry, vol. 1, pt. 2, p. 954, 1885.

calcium carbonate. Calcium sulphate is more soluble in natural water than calcium carbonate, but rivers carry much more carbonate than sulphate to the sea, because calcium carbonate is much more abundant on the land.

The secretion of calcium carbonate by organisms does not depend on the quantity of the carbonate contained in the water; it may be carried on when the quantity in solution is very small. The principal deposits of calcium carbonate which have ultimately formed limestone have been made through the agency of plants and animals and consist of oolites, shells, skeletons, coral, bones, and teeth. Some of these deposits show more or less distinctly the fossil remains of the organisms that played so important a part in their formation, but others, on account of the fineness to which the fragments were broken by the waves prior to their consolidation into rock masses, show no trace of their organic origin. Although it is probable that the larger part of the calcium carbonate deposits in the open sea are of organic origin, it is equally probable that in closed seas, in which the conditions are favorable for concentration, direct precipitation of calcium carbonate may take place.

That the influence of bacteria upon the precipitation of calcium carbonate from solution in sea water is of much importance is now recognized. With regard to the formation of the Bahaman and Floridian oolites, Vaughan[1] states:

> 1. Denitrifying bacteria are very active in the shoal waters of both regions and are precipitating enormous quantities of calcium carbonate, which is largely aragonite.
>
> 2. This chemically precipitated calcium carbonate may form spherulites or small balls which by accretion may become oolite grains of the usual size, or it may accumulate around a variety of nuclei to build such grains.
>
> The deduction may be made that all marine oolites originally composed of calcium carbonate, of whatever age, may confidently be attributed to this process.

Walcott[2] has called attention to the presence of numerous reefs of algal deposits at several horizons in the Newland limestone of the Belt series in Montana, some 9,000 feet below the base of the Cambrian, and of isolated concretion-like forms scattered at various levels in the overlying Spokane shale of the Belt Mountains. Many forms of algal remains occur in these deposits. Some of them are strikingly similar to the fresh-water lake and stream blue-green algal deposits of New York, Pennsylvania, and Michigan; others are

[1] Vaughan, T. W., Preliminary remarks on the geology of the Bahamas, with special reference to the origin of the Bahaman and Floridian oolites: Carnegie Inst. Washington Papers from Tortugas Laboratory, vol. 5, pp. 53–54, 1914.

[2] Walcott, C. D., Pre-Paleozoic algal deposits (paper delivered before Botanical Society of Washington, Apr. 6, 1915; abstract in Washington Acad. Sci. Jour., Dec. 4, 1915, p. 649).

similar in appearance to the blue-green and green algal deposits of the thermal waters of Yellowstone National Park.

According to Clarke,[1]

It is evident that important limestones may be formed in various ways which, however, are chemically the same. Calcium carbonate, withdrawn from fresh or salt water, is laid down under diverse conditions, yielding masses which resemble one another only in composition. An oceanic ooze may produce a soft, flour-like substance, such as chalk, or a mixture of carbonate and sand, or one of carbonate and mud or clay. Calcium carbonate, transported as a silt, may solidify to a very smooth fine-grained rock, while shells and coral yield a coarse structure, full of angular fragments and visible organic remains. Buried under other sediments, any of these rocks may be still further modified, the fossils becoming more or less obliterated, until in the extreme case of metamorphism a crystalline limestone is formed. All trace of organic origin has then vanished, a change which both heat and pressure have combined to bring about, aided perhaps by the traces of moisture from which few rocks are free.

CHARACTER OF LIMESTONE.

Limestone, from which marble is derived, includes rocks of many and widely varying types, differing in origin, color, texture, hardness, structure, and composition. The one property they have in common is that of consisting largely of the mineral calcite or calcium carbonate ($CaCO_3$) or of the mineral dolomite, a combination of calcium and magnesium carbonates ($CaCO_3.MgCO_3$). No natural limestones are chemically pure, however, and few are nearly so. All contain more or less foreign material, either chemically combined or as admixed minerals. The more common of these foreign substances are magnesium carbonate ($MgCO_3$), ferrous carbonate ($FeCO_3$), ferrous oxide (FeO), ferric oxide (Fe_2O_3), silica (SiO_2), alumina (Al_2O_3), clay, carbonaceous matter, mica, talc, and minerals of the pyroxene group. The colors and stains commonly noted in limestones are due to the presence of foreign minerals. The light-blue, buff, yellow, pink, red, and brown shades are due largely to iron compounds, and many of the grays and blacks are due to the presence of carbonaceous matter derived from organic remains. Manganese oxides also act as coloring agents.

VARIETIES OF LIMESTONE.

The common varieties of nonmetamorphosed limestone described below are often used as commercial marble. They may be distinguished chiefly by texture.

1. Dense, fine-grained limestone. Rock of this type generally takes a good polish and if of suitable color may be used as marble. Many of the black marbles are simply dense, fine-grained dark-blue

[1] Clarke, F. W., The data of geochemistry, 3d ed.: U. S. Geol. Survey Bull. 616, pp. 555–556, 1916.

limestone. A typical example is the black limestone at Isle La Motte, Vt., which is extensively used for decoration throughout the United States.

2. Crystalline limestone. Limestone of this type generally takes a good polish, and where of attractive color and of even grain is quarried as marble. Well-known examples are the beds quarried at Knoxville, Tenn., and Carthage, Mo.

3. Travertine and "onyx marble." These forms of calcium carbonate are precipitated by lime-bearing waters. Travertine, often called calcareous tufa, is massive porous to compact limestone, found generally over the faces of limestone bluffs, also filling crevices in limestone and around springs. It does not occur in many places in sufficient quantities and of the requisite purity and color to be of service, although it has been used as an ornamental structural material, notably in the floors, stairways, and parts of the interior walls of the concourse of the Pennsylvania Railroad station in New York City, which are constructed of a gray travertine from Italy. "Onyx marble," on the other hand, is found in workable quantities in many places, such as caves and shallow rock basins where waters have been slowly evaporated. It is very finely crystalline; is generally banded, in some places delicately, in others brilliantly; and takes a high polish. Oxidized compounds of iron and manganese produce the bright bands and colored veins that are characteristic of "onyx marble." The present supply of "onyx marble" used in the United States comes principally from Lower California, southern California, and Arizona, where it has been deposited from waters issuing from hot springs.

Certain varieties of limestone are best distinguished by their chemical composition. Among these are high-calcium limestone, magnesian limestone, dolomite, argillaceous limestone, and siliceous limestone, although, of course, the distinctions between some of them are not sharp and the varieties grade insensibly into one another.

The distinguishing characteristic of high-calcium limestone is its freedom from magnesium, as well as from ingredients regarded as impurities, such as silica, alumina, the oxides and sulphides of iron, alkalies, phosphates, and organic matter. High-calcium limestone carries from 90 to more than 99 per cent of calcium carbonate and may embrace all the physical varieties of limestone except cherty rock.

Magnesian limestone contains magnesium carbonate in any quantity up to 45.65 per cent. Most magnesian limestones carry either a small or a high percentage of magnesium carbonate, although there are a few deposits that are intermediate in composition. Magnesian limestone may embrace several varieties, texturally.

Dolomite is a mineral composed of the double carbonate of calcium and magnesium. It contains 54.35 per cent $CaCO_3$ and 45.65 per cent

$MgCO_3$.[1] In practice magnesian limestone containing 20 per cent or more of magnesium carbonate has generally been called dolomite, but it would be preferable if magnesian limestone could be distinguished as "low-magnesium" and "high-magnesium," the term "dolomite" being restricted to rock containing nearly, if not quite, the theoretical quantity of magnesium carbonate necessary to combine with the calcium carbonate in the proportions given above, or in the ratio of 1:1.19. The mineral dolomite in places forms rock masses, in which the crystals of dolomite can be distinguished. In some rocks these crystals make up a large proportion of the beds, and on weathering the rock crumbles to a sand composed of dolomite grains. The texture of magnesian limestone and dolomite is commonly granular, and hence rougher on weathered surfaces than that of high-calcium limestone. The rock is also generally more permeable than high-calcium stone.

Magnesian and dolomite marbles occur in many places and are satisfactory as building and ornamental stone, provided they are homogeneous in composition and texture. Compared with high-calcium marble dolomite marble is a little harder, withstands greater pressure, and, according to a series of tests made by Merrill[1] to determine the relative solubility of certain calcareous rocks used for building and ornamental work and also the manner in which the solvent acted, appears to be less readily affected by moisture laden with carbon dioxide. The ultimate aim of the experiments was to ascertain how the stones would withstand the effects of an atmosphere containing carbon dioxide, which would make the rain acid. Dolomite is likely to be more permeable to moisture than high-calcium stone, however, and if so, would dissolve more rapidly. Marble containing bands of both high-calcium and high-magnesium stone should therefore not be used for exposed work on account of its liability to differential weathering.

Argillaceous limestone contains a considerable proportion of clay material, consisting mainly of silicate of alumina. Clay material was probably introduced into the limestone during its formation on the sea bottom. Limestone of this character is not suitable for building stone, because it disintegrates too rapidly. It is used to a small extent in the manufacture of cement.

Siliceous limestone is a rock containing fine silica sand that was deposited with calcareous sediments in the sea. Other varieties of limestone contain silica in the form of chert, segregated in nodules and bands and in the form of crystalline quartz that has been introduced by mineral-bearing waters into the pores of the rock and into

[1] Dana, E. S., A textbook of mineralogy, p. 358, New York, John Wiley & Sons, 1900.

[2] Merrill, G. P., Report on some carbonic-acid tests on the weathering of marbles and limestones: U. S. Nat. Mus. Proc., vol. 49, pp. 347–349, 1915.

cavities, forming geodes and veins. Some limestones also contain a siliceous cement. Exceptionally, limestone may contain calcium silicate in the form of wollastonite, produced by igneous metamorphism.

DEFINITION OF MARBLE.

Marble is a term applied commercially to a granular crystalline limestone or dolomite, and even to other rocks, such as serpentine,[1] that are susceptible of polish and possess attractive colors. Scientifically, marble is a rock composed mainly of granular crystalline calcite or dolomite or of both.

METAMORPHISM.

In the formation of marble from limestone, crystallization has resulted from the effects of heat and pressure, usually aided by the action of water. The calcite or dolomite crystals in a thin section of marble are generally irregular in size, shape, and arrangement, and many of them are twinned. Crystallization has probably occurred below the surface of the earth long before the rocks were brought into their present position by crustal elevation and erosion. True marbles are therefore found in regions that have been subjected to metamorphic action, and they are associated with other metamorphic rocks, such as gneiss, schist, quartzite, and slate, and are usually situated near areas of igneous rocks, such as granite and diorite. Little chemical change takes place during the metamorphism of pure limestone and dolomite to marble, but the rock mass becomes more completely crystalline. Deposits of marble occur in the form of lenticular masses, interbedded with other metamorphosed rocks, and also in zones along the contact of a limestone with an igneous rock. If the original limestone contains silica and other impurities, certain silicate minerals may be developed in the marble.

CHEMICAL COMPOSITION.

High-calcium limestone and calcite marble contain from 90 to more than 99 per cent calcium carbonate. Pure dolomite, either nonmetamorphosed or metamorphosed, consists of approximately 54 per cent calcium carbonate and 46 per cent magnesium carbonate, but in most dolomites the percentages are slightly lower on account of the presence in the rock of foreign minerals or impurities. Marbles that are mixtures of calcite and dolomite may be of intermediate compositions. A good example of calcite marble is described on page 68. This

[1] Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, pp. 49–50, 1912. Dale describes among the commercial marbles of Vermont a serpentine and a chrome-mica schist. It is interesting to note that some of the most handsome polished samples of banded and colored marble produced recently in Alaska owe their distinctive banding to their schistose character.

marble, the white variety from Tokeen, Alaska, contained 99.51 per cent of calcium carbonate, and a dolomitic marble from Admiralty Island, Marble Cove (p. 52), contained 61.11 per cent of calcium carbonate and 39.10 per cent of magnesium carbonate. Dale[1] mentions similar examples from Vermont. A white marble quarried near Proctor, Vt., contained 98.37 per cent of calcium carbonate and a white dolomite marble quarried at Lee, Mass., contained 55.14 per cent of calcium carbonate and 43.88 per cent of magnesium carbonate. A piece of white and gray veined marble from Tokeen, Alaska (p. 69), proved to be megnesian, containing 81.90 per cent of calcium carbonate and 14.93 per cent of magnesium carbonate. A crystalline limestone of intermediate composition from Tuckahoe, N. Y., is stated by Kemp[2] to contain 70.1 per cent of calcium carbonate and 25.40 per cent of magnesium carbonate. Serpentine and schistose marbles vary greatly in composition from the proportions given above.

Among the common impurities in limestone and marble are varying percentages of silica, alumina, iron oxides and carbonates, iron pyrites and marcasite (iron disulphide), manganese oxides, gypsum, alkalies, and carbonaceous material, including graphite. Clay is introduced into the limestone beds while the sediments are being deposited on the sea bottom and is most commonly found along the bedding places, but it is also disseminated through the rock. Clay also results from the decomposition of impure limestone and marble in the process of weathering at the surface, in joint cracks that have been enlarged by solution, and in solution channels and caves. Surface clay is carried down into cracks, crevices, and irregularities in the rock surface, and in quarries that are operated on a large scale it is difficult to separate this clay cheaply from the associated rock. Silica is both an original and a secondary impurity in limestone. In ordinary hard limestone it occurs as nodules or masses of chert (flint) or else combined with alumina as clay matter. In marble it is usually found combined with some other mineral, such as alumina, iron, calcium, or magnesium, and occurs, therefore, in the form of silicate minerals. Alumina is commonly present in combination with silica in silicate minerals or as clay matter. Iron compounds may have been disseminated with the original sediments, but they have also been brought in by percolating waters. Chemical action between the iron compounds and the calcium carbonate and other minerals has resulted in the replacement of particles of calcite by iron compounds. Sulphur is present in iron disulphide and in gypsum ($CaSO_4.2H_2O$), so that it is not free under ordinary conditions. The alkalies, soda and potash, occur in very small quantities in some limestones and marbles and in their clay impurities, probably in the form of silicates.

[1] Dale, T. N., op. cit., p. 13.
[2] Kemp, J. F., A handbook of rocks, 2d ed., p. 110, 1900

The impurities in marble are present chiefly as grains of definite minerals, ranging in size from those that are microscopic to those that may be readily seen by the unaided eye. Among the common mineral impurities are quartz, hematite, limonite, pyrite, marcasite, graphite, chlorite, hornblende, pyroxene, tourmaline, feldspar, biotite, muscovite, sericite, talc, epidote, tremolite, titanite, wollastonite, and diopside.

PHYSICAL PROPERTIES.

Valuable qualities possessed by most marbles are sufficient hardness, cohesiveness, and strength for the purposes to which they are most adaptable, slight translucence, moderate specific gravity, pleasing textures and colors, and susceptibility to polish. Other properties that must be considered in connection with the use of marble for certain purposes are its rift or grain, solubility, porosity, permeability, elasticity, expansiveness under heat, flexibility, deformation under pressure, thermal conductivity, and sonorousness, but some of these properties are chiefly of scientific interest.

The physical properties of marble have been described at some length in bulletins by Dale [1] and Bowles,[2] both of which are available for free distribution, and therefore this subject will not be discussed further here. The paper by Bowles should be in the hands of all who contemplate opening marble quarries, as well as of those who are now engaged in quarrying marble.

WEATHERING.

On the outcrop and just beneath a cover of residual clay, débris, and soil, limestones and marbles are generally disintegrated, or weathered, and stained to depths depending on the physical and chemical character of the stone and on climatic and atmospheric conditions. Impurities occur in greater proportion in the weathered rock than in the unweathered, because they are less soluble than calcium carbonate.

THE MARBLE DEPOSITS.

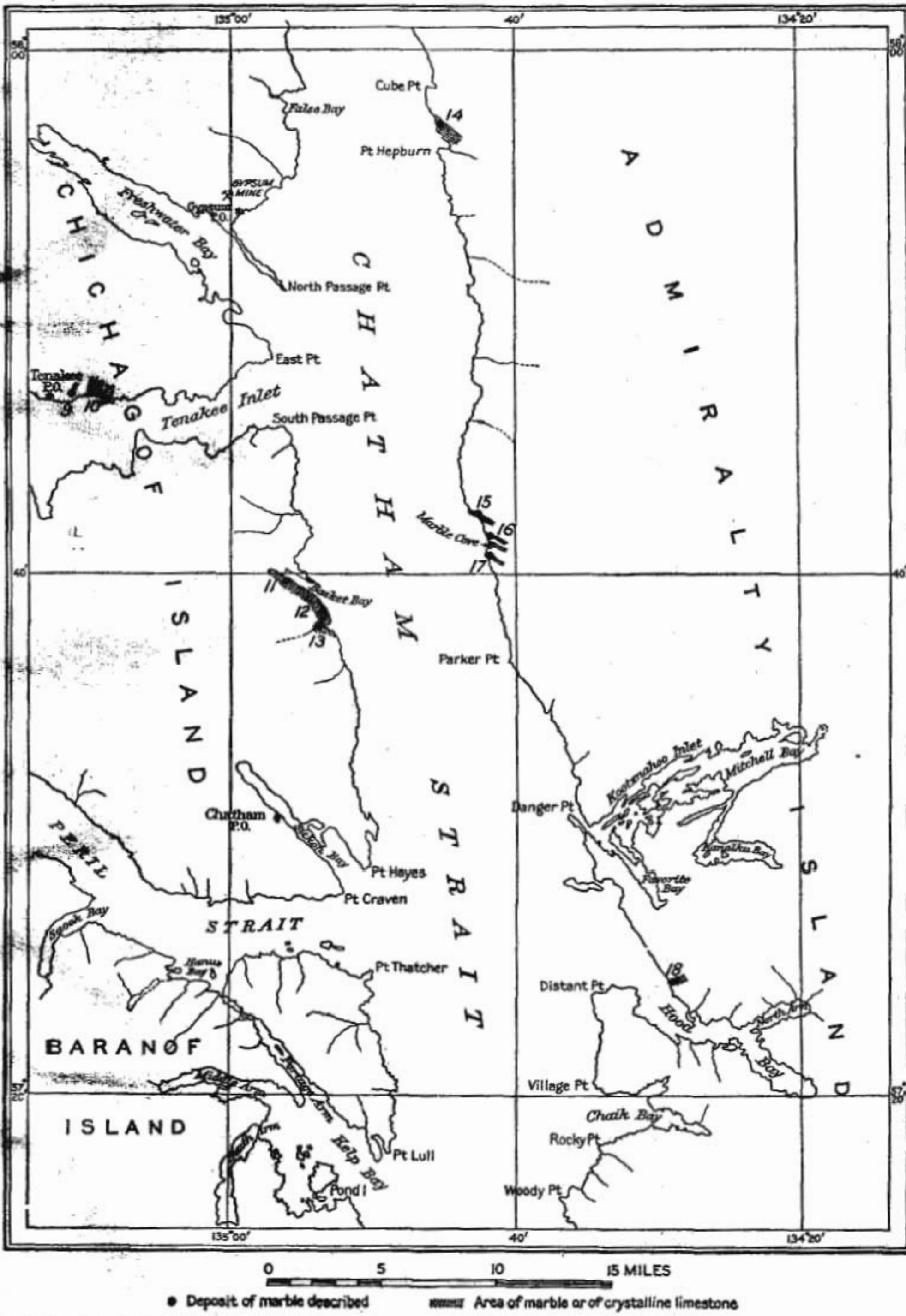
By E. F. BURCHARD.

GEOGRAPHIC DISTRIBUTION.

The mineral lands of southeastern Alaska lie in the Juneau, Skagway, Sitka, Wrangell, and Ketchikan mining districts, the outlines of which are shown on the index map (Pl. I). Deposits of marble have been found in all these districts. On some of them claims have been filed and prospecting has been done, according to regulations, and on some sufficient development work has been done

[1] Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, 170 pp., 1912.

[2] Bowles, Oliver, The technology of marble quarrying: Bur. Mines Bull. 106, 174 pp., 1916.



MAP SHOWING MARBLE DEPOSITS EXAMINED ON CHICHAGOF AND ADMIRALTY ISLANDS.

From Coast and Geodetic Survey chart No. 8306.

to warrant the issue of patents; but on some of the deposits described herein no claims have yet been filed, and on others little or nothing has been done besides filing claims. In the Juneau district deposits of marble have been noted on the mainland and on Admiralty Island; in the Skagway district marble occurs on the mainland on the east side of Glacier Bay and on several small islands in the bay; in the Sitka district marble forms some of the shore line of the southeastern part of Chichagof Island; in the Wrangell district the marble occurs chiefly on the mainland east of Wrangell Island, but a little has been noted on Kupreanof Island; in the Ketchikan district marble is widespread and abundant, having been found in both the northern and southern parts of Prince of Wales Island and on Kosciusko, Marble, Orr, Heceta, Dall, Long, and Revillagigedo islands. The relations of all these localities are shown on the index map (Pl. I) and Plates II to V and figures 1 and 4 show on a larger scale the geography of the several marble-bearing localities. Such geologic maps of this region as have been published are mainly of a reconnaissance nature and are included in Survey Bulletins 287 and 347. The maps showing the geography of the region in greatest detail are the charts issued by the Coast and Geodetic Survey, Department of Commerce, and these maps served as bases for Plates II to V and figures 1 and 4. The principal Coast and Geodetic Survey charts covering the areas containing the marble deposits of southeastern Alaska are as follows:

8100. Revillagigedo Island and southeastern part of Prince of Wales Island.

8150. Western part of Prince of Wales Island, Kosciusko, Marble, Orr, Heceta, Dall, and Long islands.

8200. Northern part of Prince of Wales Island, Kupreanof Island, Wrangell Island, and mainland to the east.

8250. Eastern part of Chichagof Island and western part of Admiralty Island.

8300. Mainland on Stephens Passage.

8306. Glacier Bay.

These charts, with the exception of No. 8306, which is on a scale of 1:160,000, or about 0.39 inch to 1 statute mile, are on a scale of 1:200,000, or approximately 0.32 inch to the statute mile.

TOPOGRAPHIC RELATIONS.

The mainland and islands of southeastern Alaska are generally mountainous, and there is little level land either as upland area or along the shores. (See Pls. I–V and figs. 1 and 4.) Along much of the coast line the hills and mountains rise abruptly and the dense forest growth, extending down to the level of high tide, overhangs the steep banks. The islands are separated by an intricate system of waterways and fiords, known locally as straits, canals, channels, passages, sounds, narrows, inlets, bays, coves, and arms, some of which reach far inland. Many of these waterways are very deep and can be safely navigated by the largest ocean steamers, but some are so shallow as to be navigable only at high tide by boats of moderate draft. The coast and entrances to harbors are rocky, and in places the greatest care is necessary in navigation in order to avoid rocks that are barely submerged. The topography is so rough that only in favored localities or at great expense can wagon or tram roads be constructed. The waterways are therefore of great value in affording routes of communication between different portions of the region and between this region and the Pacific coast ports of the United States. Indeed, were it not for water transportation the mining and quarrying industries in southeastern Alaska could scarcely have been developed.

Some of the deposits of marble are situated on the shores of sheltered bays that are deep enough to afford anchorage or wharfage for ocean-going freight vessels. Others, however, are on rocky, exposed portions of the coast, and still others are a mile or more from the shore and at considerable altitudes. Naturally the deposits most convenient of access will be developed first. Freight rates have been much reduced in the last few years through competition and are reported at present to be moderate.

The rock surface is in general thickly overgrown with small to medium-sized timber and dense underbrush and has a soil cover of decayed wood, moss, and mold, from a few inches to 3 or 4 feet thick as a rule, but thicker in hollows and crevices in the rock. The timber consists of hemlock, spruce, and cedar, which have in few places a maximum diameter of more than 4 feet. At the north, in the vicinity of Glacier Bay, the timber is much smaller, but the underbrush is dense.

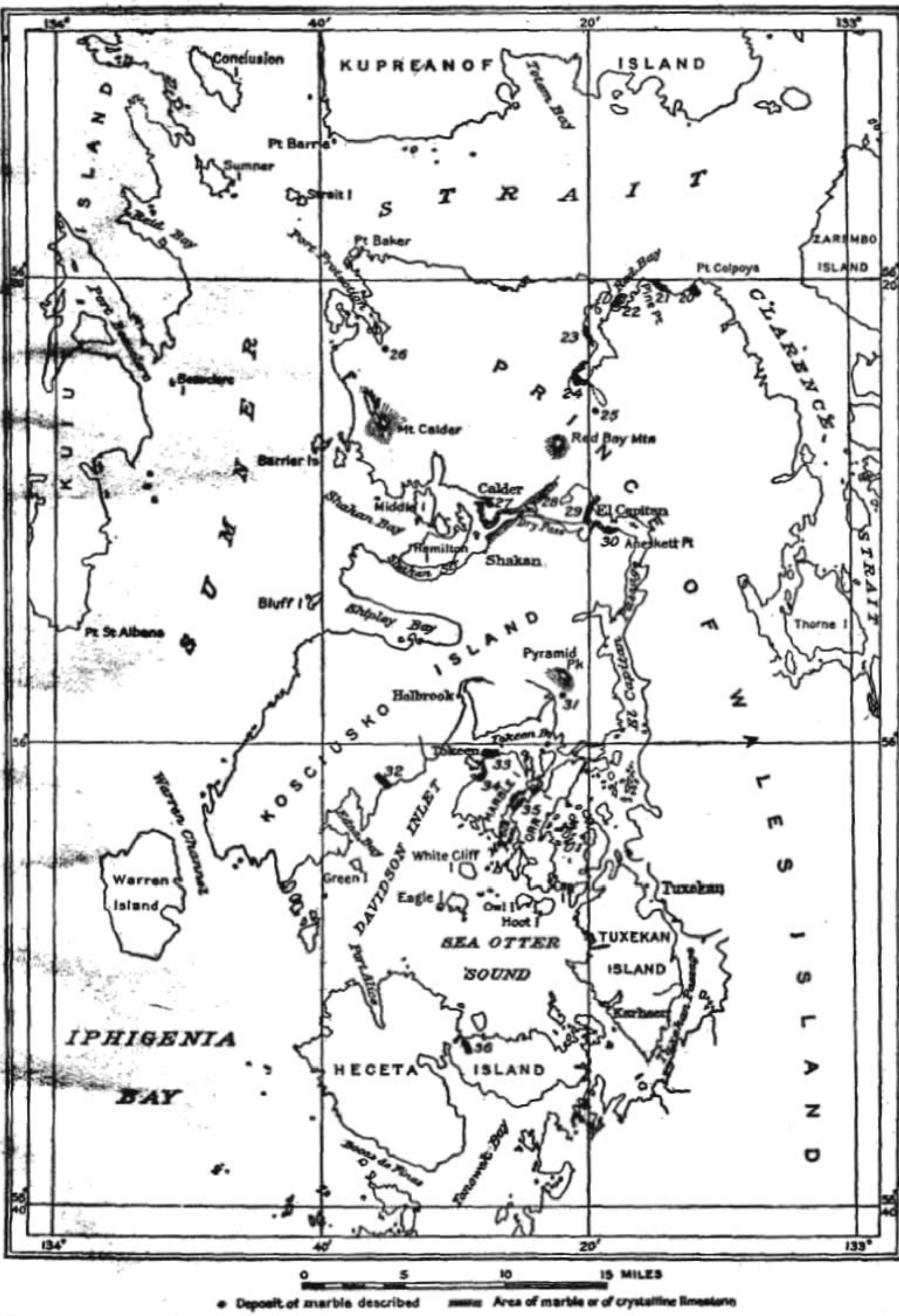
The following paragraph, by Wright,[1] on the growth of vegetation is of interest here:

> The luxuriant growth of vegetation along the coast of southeastern Alaska may well be compared with that of a tropical region. This is caused by the moist and temperate climate and the long summer days at this high altitude. At elevations below 1,500 feet bushes, ferns, and tall grasses grow profusely, especially in the valleys and gulches. These form in places a dense and almost impassable undergrowth and are a great hindrance to the prospector. Among the most common of these shrubs are the thorny devil's club, the salmonberry, the elderberry, the huckleberry, the high-bush cranberry, various willows, the black alder, and the white alder, the latter forming thickets along the streams and mud flats.

GEOLOGIC RELATIONS.

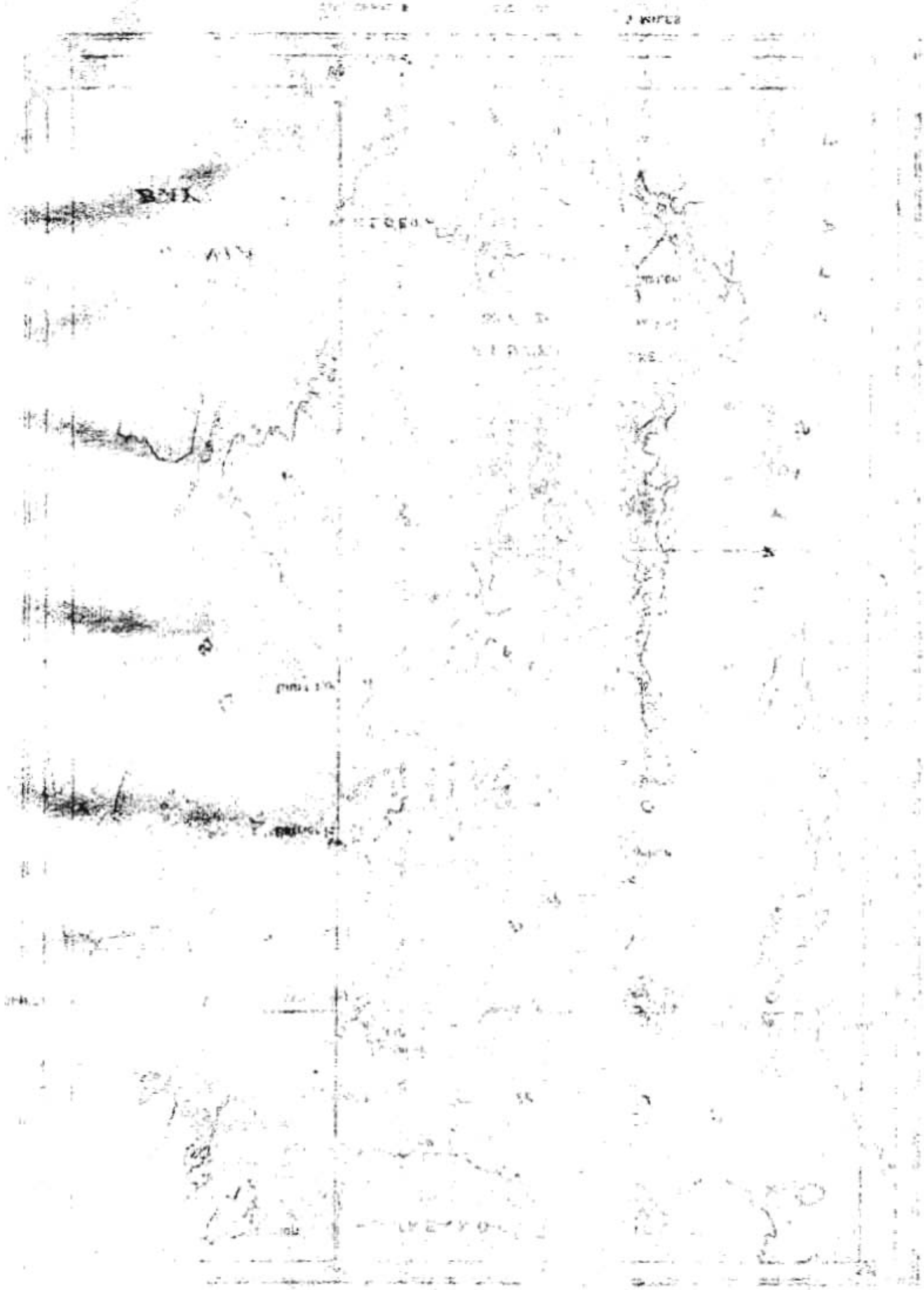
Most of the marble beds in southeastern Alaska appear to be portions of extensive belts of limestone that have been metamorphosed by an intrusive mass of granodiorite at or near the contact,

[1] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 31, 1908.



MAP SHOWING MARBLE DEPOSITS EXAMINED ON NORTHERN PRINCE OF WALES ISLAND AND ON KOSCIUSKO, MARBLE, ORR, AND HECETA ISLANDS.

From Coast and Geodetic Survey charts Nos. 8200 and 8150.


2 MILES
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or by the general metamorphism of the region, or by a combination of the two agencies. The relations of the belts of sedimentary and intrusive rocks are shown in Plate I. Both the limestone and the marble are cut in many places by thin dikes, principally of basalt, andesite, dacite, and diabase, all more or less altered and containing secondary calcite, and in places the marble beds are interstratified with graywackes, schists, and lavas. Both the limestone and the marble beds are generally much fractured and jointed, the marble in places showing joints that are open to considerable depths. The limestone beds associated with the marble deposits are of Paleozoic age and at a few places, notably in and near the northern part of Prince of Wales Island, have yielded fossils that are regarded as Silurian.

TYPES OF MARBLE AVAILABLE.

Many types of marble are available in southeastern Alaska. Probably the most common and the one which thus far has been exploited commercially on the largest scale is a fine to medium grained crystalline white to bluish-gray marble with gray to dark-bluish veins, bands, and clouded areas. Other crystalline and schistose marbles that give promise of being developed successfully show handsome contrasting "verde antique" effects and other striking combinations of color, such as green and pink, black and white, and white and yellow. The green color appears to be due to chloritic material and possibly to epidote, the bluish and black veins possibly to graphite, and the pink and yellow shades to iron oxide. Certain marble deposits give promise of affording statuary material. Some dense noncrystalline limestones have attractive colors of pink and chocolate mottled, gray, blue, and black, and are susceptible of receiving a high polish.

The tabular classification or index of the principal varieties of marble in southeastern Alaska according to color given on pages 31–39 has been prepared to furnish the reader a condensed and systematic description of the marbles available and to enable him to find quickly the detailed description of any marble together with the notes concerning the locality in which it occurs.

In this classification the following varieties of marble are distinguished:

White; nearly white; cream-colored; white with gray veins (in part banded); white with dark-gray to black veins or bands; white with blue veins or bands; white with yellow veins or clouds; gray (in part veined and banded); bluish gray (some banded with white); pearl-gray; light blue; black (blue-black); green and banded with green; pink (also pink and white); yellow; mottled, chiefly red and white, red and gray, brown and white; variegated colors; schistose (varicolored bands).

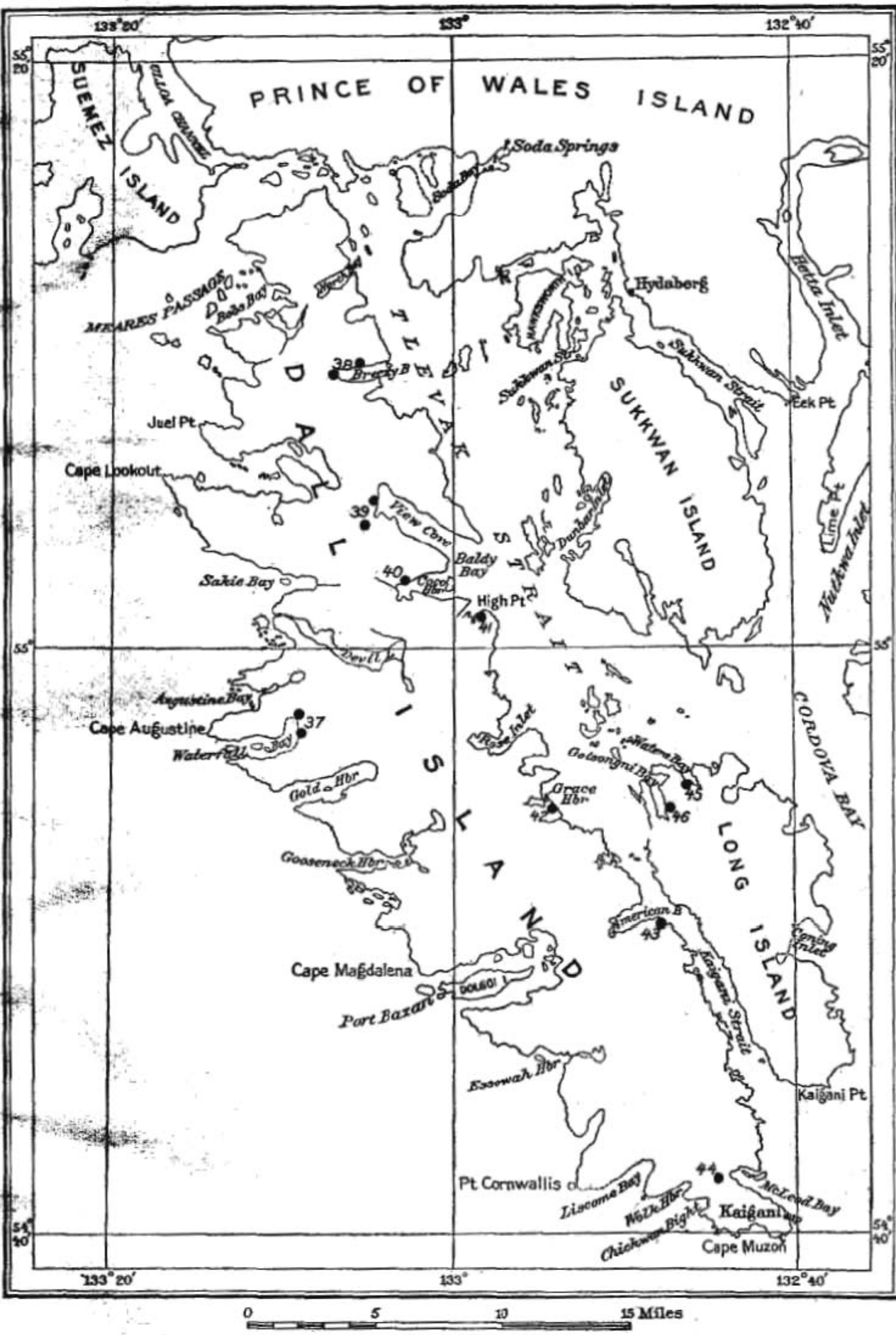
The terms "fine," "medium," and "coarse," describing the grain or grade of texture of the marbles, are here used according to a definite scale of average grain diameters. A marble is described as having a fine grain if its average grain diameter is 0.10 millimeter or less. A marble whose grain is just visible to the average unaided eye or is still finer would thus fall within the fine grade. A medium grain is one that averages from 0.11 to and including 0.50 millimeter, and a coarse grain is one that averages larger than 0.50 millimeter. A classification of Vermont marbles into six grades of texture was devised by Dale[1] but was found to be not adaptable to the wide range in texture displayed by Alaska marbles. The relation between the present classification and the Vermont marble classification is shown in the following outline:

Relation between grades of texture of Alaskan and Vermont marbles.

Name.	Alaska grade. (Average grain diameter in hundredths of a millimeter.)	Vermont grade.
Fine	10 or less	01. Finer than "extra fine." 1. Extra fine. 2. Very fine.
Medium	11 to 50	3. Fine. 4. Medium 5. Coarse.
Coarse	51 or more	6. Extra coarse. 7. Do. 8. Do.

The classification in detail is set forth on the following pages.

[1] Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, p. 54, 1912.



MAP SHOWING MARBLE DEPOSITS EXAMINED ON DALL AND LONG ISLANDS.

From Coast and Geodetic Survey chart No. 8150.

Classification of Alaska marbles.

White.

Locality.	Texture.	Average grain diameter, in hundredths of a millimeter.	Vermont grade.	Grain form.	Petrographic name.	Development.	No. on map (Pl. I).	Described on pages—
South Marble Island, Glacier Bay	Medium	20	4-6	Uneven	Calcite marble	None	7	44
Chichagof Island, Basket Bay	Fine			Even, elongate	Magnesian calcite marble	do	11	46-47
Chichagof Island, cove south of Basket Bay	do	8	2	Even	Calcite marble	do	13	48
Admiralty Island, Marble Cove	do			do	do	do	17	52
Admiralty Island, one-third mile south of Marble Cove.	Medium	46	5-6	Uneven	Calcite marble, with dusty inclusion of carbonaceous (?) material.	do	17	52-53
Admiralty Island, Hood Bay	Fine	9	2	Even	Calcite marble	do	18	54-55
Prince of Wales Island, Shakan Bay (Calder)	Medium	16	4	Uneven	do	Quarry	27	60-62
Prince of Wales Island, Dry Pass	Coarse	174	8	Even	do	None	28	62-63
Prince of Wales Island, El Capitan	Medium	12-15	3	Uneven	do	Prospect	29	63-64
Marble Island, Tokeen	do	31	5	do	do	Quarry	33	68, 70
Marble Island, 1¼ miles southwest of Tokeen	do				do	Prospect	34	72-73
Dall Island, Waterfall Bay	Fine	5	01	Even	Calcite marble, with a little sericite.	do	37	77-80
Dall Island, Coco Harbor	do	6	1	do	Calcite marble	None	40	82
Long Island, Waters Bay	Medium	15	4	do	do	Prospect	45	83-84
Long Island, Gotsougni Bay	do	25	6	do	do	do	46	84-85
Prince of Wales Island, Dolomi	Fine			Uneven	Calcite marble, with a little alumina, silica, and pyrite.	Abandoned quarry	47, 48	85-86
Revillagigedo Island, Carroll Inlet	do	10	2	Even	Dolomite marble	Prospect	58	97

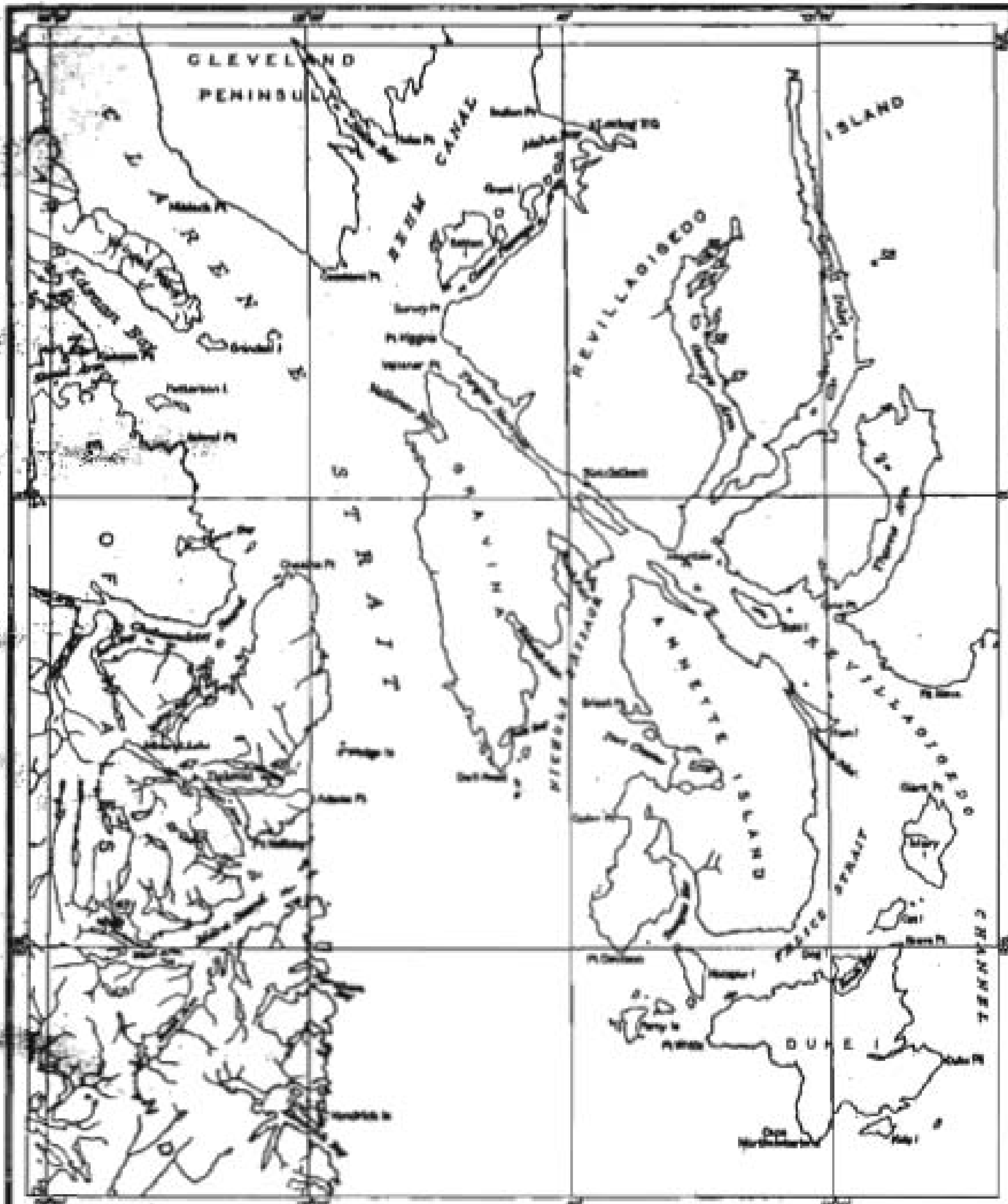
Classification of Alaska marbles—Continued.

Nearly white.

Locality.	Texture.	Average grain diameter, in hundredths of a millimeter.	Vermont grade.	Grain form.	Petrographic name.	Development.	No. on map (Pl. I).	Described on pages—
Limestone Inlet, Mainland	Medium	20	5	Irregular	Calcite marble	Prospect	1	40
Willoughby Island, Glacier Bay	Medium to coarse			Uneven	do	None	8	44–45
Chichagof Island, Tenakee Inlet	Coarse			do	Calcite marble, in part schistose	do	9	45
Do	Fine	4	01	Even	Calcite marble with grains of pyrite, feldspar, quartz, and chlorite.	do	10	45–46
Do	Fine groundmass with coarse crystals.	7–89	1–7	Uneven	Calcite marble with curved twinned brecciated plates.	do	10	45–46
Chichagof Island, Basket Bay	Fine	9	2	Even, elongate	Magnesian calcite marble	do	11	46–47
Prince of Wales Island, Point Colpoys	do			Even	Calcite marble	Prospect	20	56–57
Prince of Wales Island, head of Port Protection.	do			Uneven	Limestone, partly metamorphosed in places.	None	26	59
Kosciusko Island, opposite El Capitan	do			do	Calcite marble cut by thin seams of quartz.	Prospect	30	64–65
Marble Island, Orr Inlet	Medium to coarse			do	Calcite marble	do	36	74
Dall Island, Baldy Bay	Medium			do	Calcite marble with a few grains of pyrite.	None	41	82
Dall Island, Grace Harbor	Fine			Even	Calcite marble	do	42	82
Prince of Wales Island, Dickman Bay	do	10	2	Uneven	do	Prospect	49	86–90
Eastern Passage, near Lake Virginia	Coarse			do	Talcose calcite marble	None	50	91–92
Blake Channel	Medium			do	Calcite marble	Prospect	51	92–93
Ham Island	Coarse	139–364	8	do	do	do	52	93–95
Revillagigedo Island, George Inlet	Fine to medium			do	Schistose calcite marble	None	55, 56, 57	96–97

Cream colored.

Locality.	Texture.	Average grain diameter, in hundredths of a millimeter.	Vermont grade.	Grain form.	Petrographic name.	Development.	No. on map (Pl. I).	Described on pages—
Mainland, Glacier Bay, south of Sandy Cove	Fine			Uneven	Calcite marble	None	3	41
Willoughby Island, Glacier Bay	Medium	46	6	do	Calcite marble, cherty in places	do	8	44–45
Prince of Wales Island, west side of Red Bay	Fine			do	Calcite marble	Prospect	23	57–58



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Deposit of marble described — Area of marble or of crystalline limestone

MAP SHOWING MARBLE DEPOSITS EXAMINED ON SOUTHEASTERN PRINCE OF WALES ISLAND AND ON REVILLAGIGEDO ISLAND.

From Coast and Geodetic Survey chart No. 8100.

White with gray veins (in part banded).

South Marble Island, Glacier Bay	Medium	20	4-5	Even	Calcite marble	None	7	44
Admiralty Island, one-third mile north of Marble Cove.	do	36	5-6	Slightly uneven	do	do	15	50-52
Do	do	5-29	1-5	Uneven, banded	Calcite marble with mica, tremolite, and possibly pyrite and graphite.	do	17	52-53
Prince of Wales Island, head of Red Bay	do	20	5	Uneven	Calcite marble	Drill prospect	24	58-59
Prince of Wales Island, El Capitan	do	15	4	do	do	Quarry	29	63-64
Kosciusko Island, head of Tokeen Bay	do			do	do	Prospect	31	65
Marble Island, Tokeen	do	13	3	Very uneven	Magnesian calcite marble	Quarry	33	68-69

White with dark-gray to black veins or bands.

Marble Island, Tokeen	Medium	13	3	Very uneven	Magnesian calcite marble	Quarry	33	68-69
Orr Island	Fine to coarse	10-89	2-8	Uneven	Calcite marble, with a little magnesia and silica.	do	35	74-76
Dall Island, View Cove	Medium			do	Calcite marble	None	39	80-81
Long Island, Waters Bay	do	12	3	do	Calcite marble with graphitic bands	Prospect	45	83-84

White with blue veins or bands.

Prince of Wales Island, Shakan Bay (Calder)	Fine			Uneven	Calcite marble	Quarry	27	60-62
Long Island, Waters Bay	Medium	12	3	do	Calcite marble with graphitic bands	Prospect	45	83-84
Prince of Wales Island, Dickman Bay	do	13	3	do	do	do	49	86-90

White with yellow veins or clouds.

Dall Island, Waterfall Bay	Fine			Even	Calcite marble	Prospect	37	77-80
Dall Island, Grace Harbor	do			(?)	(?)	None	42	82
Prince of Wales Island, Dickman Bay	do	10	2	Uneven	Calcite marble	Prospect	49	86-90

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Classification of Alaska marbles—Continued.

Gray (in part veined and banded).

Locality.	Texture.	Average grain diameter, in hundredths of a millimeter.	Vermont grade.	Grain form.	Petrographic name.	Development.	No. on map (Pl. I).	Described on pages—
Mainland, Limestone Inlet	Medium	26	5	Uneven	Calcite marble	Prospect	1	40
Mainland, Glacier Bay, Sandy Cove	do			Irregular	Calcite marble, slightly magnesian in places.	None	2	41
Mainland, Glacier Bay, south of Sandy Cove	Fine			Uneven	Nonmetamorphosed limestone	Prospect	3, 4	41, 43
North Marble Island, Glacier Bay	Medium	25	5	do	Calcite marble	None	6	43–44
Willoughby Island, Glacier Bay	do	46	Coarse. 6	do	Partly metamorphosed limestone	do	8	44–45
Chichagof Island, Tenakee Inlet	Fine			do	Calcite marble, pyritiferous in places.	do	10	45–46
Chichagof Island, Basket Bay	do	7	01	do	Graphitic magnesian calcite marble	do	11	46–47
Prince of Wales Island, 2 miles west of Point Colpoys.	do			Even	Limestone, slightly metamorphosed in places.	Prospect	21	57
Prince of Wales Island, west shore of Red Bay.	do	5	01–1	Uneven	Calcite marble	do	23	57–58
Prince of Wales Island, head of Port Protection.	do			do	Limestone, partly metamorphosed in places.	None	26	59
Prince of Wales Island, Dry Pass	Coarse	84	7	do	Calcite marble	do	28	62–63
Kosciusko Island, opposite El Capitan	Fine			do	Calcite marble cut by thin seams of quartz.	Prospect	36	76–77
Dall Island, Waterfall Bay	do	4	01	do	Calcite marble	do	37	77–80
Dall Island, Breezy Bay	do				do	None	38	80
Dall Island, View Cove	Medium			Uneven	do	do	39	80–81
Long Island, Waters Bay	do			Even	do	Prospect	45	83–84
Prince of Wales Island, Dickman Bay	Fine			Uneven	do	do	49	86–90
Mainland, Eastern Passage, near Lake Virginia.	Medium	14	4	Even	do	None	50	91–92
Blake Channel	do	28	5	Uneven	Calcite marble with graphitic (?) streaks.	Prospect	51	92–93
Ham Island	Coarse			do	Calcite marble	do	52	93–95
Revillagigedo Island, George Inlet	Fine to medium			do	Schistose marble	None	55, 56, 57	95–97

Bluish-gray (some banded with white).

Chichagof Island, cove south of Basket Bay	Fine	8	1-2	Even	Calcite marble with minute grains of quartz and pyrite.	None	12	47-48
Kupreanof Island, Duncan Canal	Fine to coarse			Uneven	Limestone with streaks and patches of white calcite.	do	19	56
Prince of Wales Island, west shore of Red Bay.	Fine	6	1	do	Calcite marble	Prospect	23	57-58
Prince of Wales Island, Dry Pass, near "Winter Harbor."	Coarse	84	7	do	do	None	28	62-63
Kosciusko Island, head of Tokeen Bay	Fine			do	do	Prospect	31	65
Marble Island, Orr Inlet	do	4	01	do	Calcite marble with streaks of graphite.	do	35	74-76
Dall Island, Baldy Bay	Medium			do	Calcite marble with a few grains of pyrite.	None	41	80
Long Island, Gotsongni Bay	do			Even	Calcite marble	do	46	84-85
Mainland, Eastern Passage, near Lake Virginia.	Fine			do	do	do	50	91-92
Mainland, Blake Channel	Medium	25	5	Uneven	Calcite marble with graphitic (?) streaks.	Prospect	51	92-93
Ham Island	do	32	5	Uneven, elongate.	Calcite marble with a little graphite	do	52	93-95

Pearl gray.

Dall Island, View Cove	Fine	8	2	Nearly even	Calcite marble	None	39	80-81
Long Island, Waters Bay	Medium	About 23	5	Even	do	Prospect	45	83-84

Light blue.

Prince of Wales Island, Shakan Bay (Calder).	Fine			Uneven	Calcite marble	Quarry	27	60-62
Prince of Wales Island, El Capitan	Medium			do	do	Prospect	29	63-64

Classification of Alaska marbles—Continued.

Locality.	Texture.	Average grain diameter, in hundredths of a millimeter.	Vermont grade.	Grain form.	Petrographic name.	Development.	No. on map (Pl. I).	Described on pages—
Dark blue.								
Chichagof Island, Basket Bay	Fine			Uneven	Magnesian calcitic marble with streaks of calcite.	None	11	46–47
Blue and white clouded.								
Long Island, Gotsongni Bay	Medium	20	4	Even	Calcite marble	None	46	84–85
Blue and white speckled.								
Admiralty Island, one-half mile south of Marble Cove.	Medium	35	5–6	Uneven	Twinned dolomite and twinned calcite with segregations of olivene altered to serpentine and magnetite. Carbonaceous matter and sulphides also present.	None	17	53–54
Black (blue black).								
Marble Island, Tokeen	Fine	5	1	Uneven	Limestone with carbonaceous and pyrite specks.	Quarry	33	67–68
Dall Island, Waterfall Bay	do	About 3	01	do	Calcite marble	Prospect	37	77–80
Dall Island, View Cove	do			do	Limestone, partly metamorphosed, probably graphitic.	do	39	80–81
Prince of Wales Island, Dickman Bay						Quarry	49	86–90

Green and banded with green.

Mainland, Limestone Inlet	Medium	18	4-5 Medium.	Slightly irregular	Calcite marble	Prospect	1	40
Mainland, east of Sandy Cove, Glacier Bay.	Fine			Uneven	Partly metamorphosed limestone.	None	5	43
Chichagof Island, Tenakee Inlet	Coarse			do	Calcitic schistose marble	Prospect	9	45
Admiralty Island, near Point Hepburn	Fine to coarse			Very irregular	Calcitic schistose marble carrying quartz, feldspar, epidote, hornblende, and pyrite.	None	14	49-50
Kosciusko Island, near Holbrook	Fine			Uneven	Limestone breccia	Prospect		65-66
Marble Island, 1½ miles southwest of Tokeen	Fine to medium	3-24	01-5	Very uneven	Pyritiferous calcite marble with silicate minerals.	do	34	72-73
Dall Island, View Cove	Fine	4	1	Even	Calcite marble with streaks of micaceous and carbonaceous material.	None	39	80-81
Prince of Wales Island, Dickman Bay	Coarse	75	6	Uneven	Calcite marble with bands containing quartz, epidote, plagioclase, and chlorite.	Prospect	49	89-90
Do	Fine	About 5	01	do	Calcite with grains of quartz, dolomite, plagioclase, chlorite, biotite, and epidote.	do	49	89-90

Pink (also pink and white).

Dall Island, Waterfall Bay	Fine	5	1	Even	Calcite marble	Prospect	37	77-79
Long Island, Gotsongni Bay	Medium to coarse			Uneven	do	do	46	84-85

Yellow (generally yellow only in part).

[See also "Mottled."]

Kosciusko Island, 3 to 4 miles northeast of Edna Bay.	Fine			Uneven	Limestone stained with iron oxide.	Prospect	32	66
Dall Island, View Cove	do	4	1	Even	Calcite marble	None	39	80-81
Long Island, Waters Bay	Medium	25	5	Uneven	do	do	45	83-84

Classification of Alaska marbles—Continued.

Mottled (chiefly red and white, red and gray, brown and white).

Locality.	Colors.	Texture.	Average grain diameter, in hundredths of a millimeter.	Vermont grade.	Grain form.	Petrographic name.	Development.	No. on map (Pl. I).	Described on pages—
Mainland, south of Sandy Cove, Glacier Bay.	Chocolate-colored, pink, grayish green, and drab.	Fine	2-7	01-1	Uneven	Calcite marble colored by hematite and other iron oxides.	Prospect	3	41-43
Chichagof Island, Tenakee Inlet	Green, pink, and gray	do			do	Calcite marble with pyrite specks.	None	10	45-46
Prince of Wales Island, Point Colpoys.	Gray, red, and white	do			Even	Calcite marble	Prospect	20	56-57
Bells Island, Red Bay	Gray, blue, white, and pink	do			do	Limestone, slightly metamorphosed in places.	do	22	57
Prince of Wales Island, head of Red Bay.	Light gray, cream-colored, and blue.	do			Uneven	Limestone, partly metamorphosed.	None	24	58-59
Kosciusko Island, 3 to 4 miles northeast of Edna Bay.	Red, white, and yellow	do			Even	Limestone, stained with iron oxide.	Prospect	32	65
Kosciusko Island, near Holbrook	Dark and light green, and pink	do			Uneven	Limestone breccia	do		65-66
Marble Island	Bluish gray, pink, and green	Fine to medium	3-23	01-5	Very uneven.	Siliceous calcitic marble	do	34	72-73
Orr Island	Cream-colored, brownish gray, and bluish white.	Medium	25	5	Uneven	Calcite marble with a little magnesia and silica.	Quarry	35	74-76
Hecota Island	Pink, red, chocolate-colored, green, yellow, and white.	Fine			do	Limestone with silica, iron oxide, and a little magnesia.	Prospect	36	76-77
Dall Island, Waterfall Bay	White and pink	do	5	1	Even	Calcite marble	do	37	77-80
Do	Black and white	do	5	1	do	Calcite marble with graphite	do	37	77-80
Do	Bluish gray and black	do	6	1	do	Calcite marble with graphitic veins and areas.	do	37	77-80
Dall Island, View Cove	Black and gray	do	4	1	do	Calcite marble	None	39	80-81
Long Island, Waters Bay	Blue, white, and yellow	Medium	26	5	Uneven	do	do	45	83-84
Prince of Wales Island, Dickman Bay.	Green, white, pink, and black	Fine			do	Calcite, chloritic material, quartz, and hematite.	Prospect	49	86-90

Variegated colors.

Mainland, south of Sandy Cove, Glacier Bay.	Gray, bluish, cream-colored, yellow, reddish, chocolate-colored, pink, green, and drab.	Fine	2–7	01–1	Uneven	Calcite colored by hematite and other iron oxides.	Prospect	3	41–43
Prince of Wales Island, 2 miles west of Point Colpoys.		....do			Even	Limestone, slightly metamorphosed in places.	....do	31	57
Kosciusko Island, 3 to 4 miles northeast of Edna Bay.	Yellow, sienna, and red	....do			....do	Calcite marble	....do	32	66
Marble Island	Light and dark green, bluish, light pink, and brownish gray.	Fine to medium	3–23	01–5	Very uneven.	Cherty (?) calcite marble	....do	34	72–73
Kosciusko Island	Pink, red, chocolate-colored, green, yellow, and white.	Fine			Uneven	Limestone with silica, iron oxide, and a little magnesia.	....do	36	76–77
Dall Island, Waterfall Bay	Pink and white with irregular green bands.	....do	5	1	....do	Calcite marble with green bands of quartz, sericite, and chlorite.	....do		78–79 80–81
Dall Island, View Cove	Yellow with green stripe	....do	4	1	Even	Calcite marble	None	39	
Prince of Wales Island, Dickman Bay.	Gray, white, yellow, green, black, and pink.	Fine to coarse			Uneven	Calcite, quartz, mica, chloritic material, and hematite.	Prospect	40	86–90

Schistose (varicolored bands).

Mainland, Limestone Inlet	Gray, white, and grayish green	Medium			Uneven	Calcite marble with bands of hornblende mica schist.	None	1	40
Chichagof Island, Tenakee Inlet	White, green, and gray	Coarse			....do	Calcite marble with mica schist	Prospects	9	45
Admiralty Island, Point Hepburn	White, gray, green, and black	Medium	10	3–4	....do	Calcite marble with grains of quartz, feldspar, chlorite, and mica in bands.	None	14	49–50
Admiralty Island, 1 to 2 miles north of Marble Cove.	Gray, white, pink, and green	....do	16–33	4–6	....do	Calcite marble with pyroxene, epidote, tremolite, quartz, pyrite, and titanite.	....do	15, 16	50–52
Dall Island, American Bay		Fine to coarse			....do	Micaceous calcite marble	....do	43	82–83
Dall Island, near McLeod Bay	White, pink, and green	Medium			....do	Bands of calcite marble	....do	44	83
Prince of Wales Island, Dickman Bay.	White, green, yellow, gray, and black.	Fine to coarse			....do	Calcite marble, with quartz, plagioclase, chloritic material, muscovite, epidote, biotite, graphite, and hematite.	Prospects	40	86–90

THE DEPOSITS.[1]

MAINLAND AT LIMESTONE INLET.

The deposits of marble in the vicinity of Limestone Inlet are on the mainland about 26 miles south-southeast of Juneau and 2½ miles inland from the mouth of the inlet, or 1 to 1½ miles from deep water (No. 1). Outcrops on the north bank of Limestone Creek consist of medium-grained grayish-white marble, banded in places with dark-gray streaks and veins of white calcite of coarser texture. Portions of the beds have a grayish-green color, possibly due to surface stains. Some parts of the mass are schistose and carry hornblende, mica, pyrite, and thin seams of quartz. The gray and green varieties are both susceptible of a fair polish. The surface of the marble is cut by two or more sets of joints into blocks from a few inches to 3 feet thick. The strike of the rocks is apparently between N. 25° W. and N. 30° W., and the dip is steep toward the northeast.

Two samples of marble from Limestone Inlet were examined microscopically by T. N. Dale. A specimen of the grayish-white variety showed a grain diameter of 0.037 to 1.28 millimeters, mostly 0.185 to 0.74 millimeter, with an estimated average of 0.277 millimeter. By use of the Rosiwal method the average diameter of the grains was found to be 0.0103 inch, or 0.262 millimeter. The grade is therefore medium; but, compared with Vermont marbles, according to Dale's classification, this marble would fall into grade 5 (coarse). The texture is uneven, and some pyrite was noted.

A specimen of the greenish variety showed a grain diameter of 0.074 to 0.925 millimeter, mostly 0.185 to 0.555 millimeter, with an estimated average of 0.216 millimeter. The Rosiwal measurement gave an average of 0.007 inch, or 0.1778 millimeter, thus indicating a medium texture. The grain form appears a little uneven. Very little pyrite is present in the section, and quartz is rare, in minute particles.

Associated with the schistose marble are beds of hornblende mica schist. A thin section examined by J. B. Mertie showed quartz, sericite, hornblende, chlorite, epidote (derived in large part from hornblende), and sulphides.

Two groups of marble claims have been located on this deposit, and two small prospect openings about 200 feet apart have been made near the creek bank. Between these two openings several natural exposures in the bank of the creek indicate the presence of schistose marble.

Most of the marble deposit is covered by forest growth, and little could be ascertained as to its extent or structure beyond the indica-

[1] In the descriptions of deposits the numbers in parentheses refer to corresponding numbers on the index map (Pl. I) and on other maps (Pls. II to V, figs. 1 and 4).

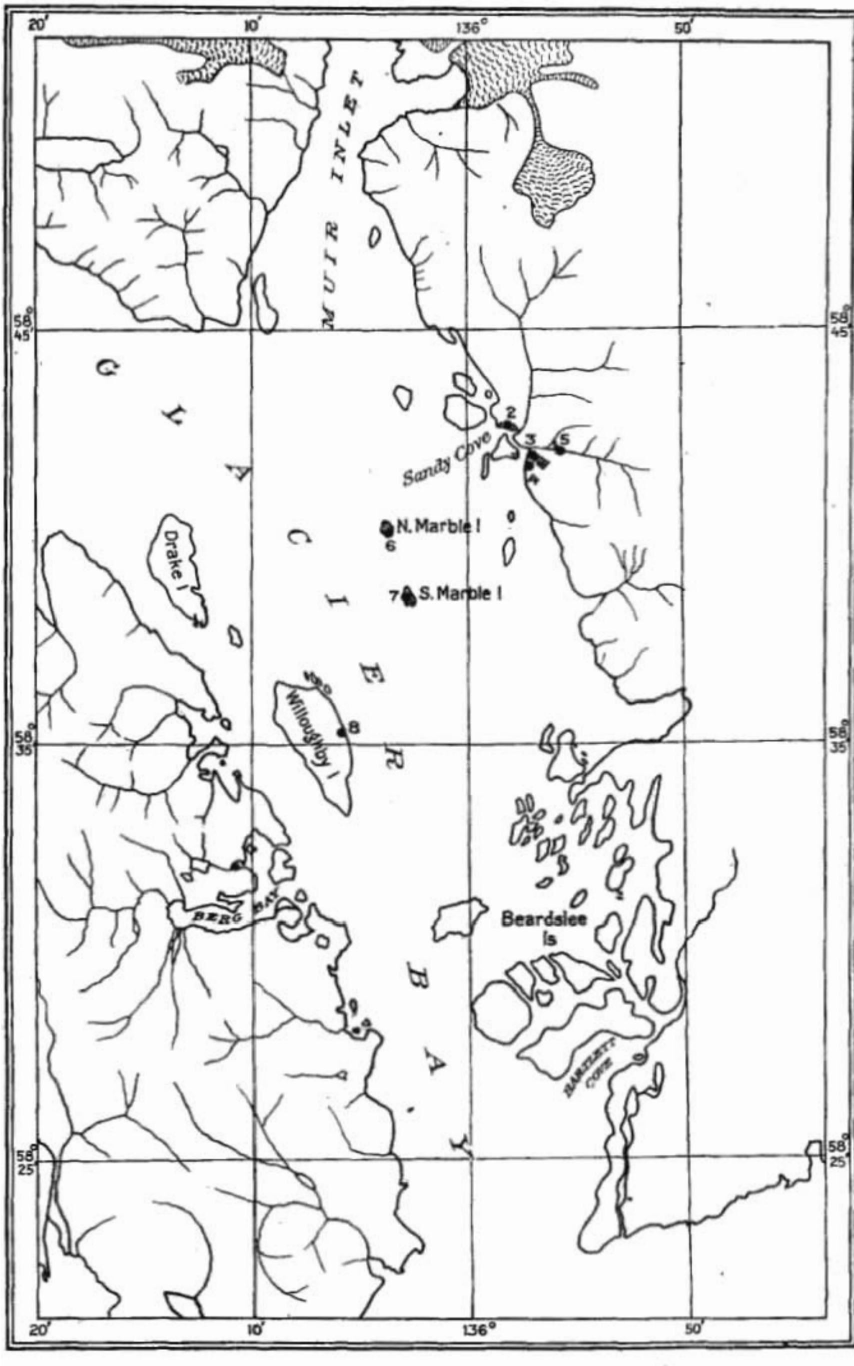
tions afforded by the few exposures. In order to develop this deposit a tramway must be built from the property down the creek to deep water in Limestone Inlet, a distance of about 1½ miles. The construction of the tramway would involve the cutting away of some rocky points and the building of half a mile or more of trestle.

MAINLAND AND ISLANDS, GLACIER BAY.

Limestone and marble deposits crop out on the mainland on the east shore of Glacier Bay in the vicinity of Sandy Cove. Along the north shore of Sandy Cove (No. 2) marble is exposed for 600 feet or more, and the deposit extends back into a low ridge 50 to 75 feet above the water. This marble is hard, of a light-grayish color, and generally of medium grain, but contains many small bodies of calcite of varying size. Nearly obliterated traces of fossil brachiopods were noted in it. The marble is brecciated in places and has been disturbed by the intrusion of dikes. Some of the brecciated portions contain magnesium carbonate. The beds here are 3 feet or more in thickness, strike northward, and dip about 40° W. Where exposed the material is so much jointed and fractured that little stone of commercial size is obtainable.

On the east shore of the cove next south of Sandy Cove (No. 3) are beds of variegated marble and partly metamorphosed limestone. The colors include gray with bluish veins, cream-colored with yellow veins, reddish, mottled chocolate-colored and pink, and mottled grayish-green and drab. The rock is fine grained, hard, and brittle and takes a good polish. It is generally much fractured at the surface, especially the gray limestone. Traces of stylolites or suture joints were observed in the gray marble. The beds strike about S. 50° E. and dip steeply toward the northeast. This belt of rocks is about 500 feet thick and extends an indefinite distance southeastward into the mountains. The bedding is variable, but for the most part the rock is fairly massive. Dikes of diabase cut the beds in east and northeast directions, and the jointing runs generally in the same directions. The ridge which the marble forms is about 50 feet high at its northwest end, where a low cliff has been cut by the stream that flows into the cove, but toward the southeast the ridge rises to 500 feet or more in height within a quarter of a mile. (See fig. 1.)

A thin section of the mottled marble was examined by T. N. Dale and G. F. Loughlin. It consists of finely granular faintly pinkish rock and coarse transparent rock in irregular alternations and inclusions. The granular part consists of untwinned but polarizing grains of calcite and contains throughout faintly reddish specks of dusty hematite. The grain diameter ranges from 0.02 to 0.047 milli-



• Deposit of marble described ▥ Area of marble or of crystalline rocks

FIGURE 1.—Map showing marble deposits examined on mainland and islands in Glacier Bay. From Coast and Geodetic Survey chart 8306.

meter, with an estimated average of 0.024 millimeter. The transparent parts consist of twinned calcite, of a grain diameter of 0.047 to 0.4 millimeter, with an estimated average of 0.725 millimeter. The texture is therefore fine.

A chemical analysis by R. K. Bailey shows that the rock consists largely of calcite with a little clay material indicated by the insoluble residue:

Analysis of mottled marble from deposit south of Sandy Cove.

Insoluble	2.56
Calcium carbonate	96.16
Magnesium carbonate	.89

Three claims, aggregating 3,960 feet in length, were at one time located on the strike of these beds, although little assessment work appeared to have been done up to the time of the writer's visit. The really desirable and commercially valuable stone is probably scarce, and much prospecting will be necessary in order to establish its true extent and value.

The bold cliffs on both sides of the entrance to the cove next south of Sandy Cove and also extending southward from it (No. 4) are composed principally of fine-grained hard, brittle, much fractured gray limestone, cut by many diabase dikes generally 2 to 10 feet thick. Along the contacts between the limestone and the larger dikes the limestone has been locally metamorphosed to white crystalline marble, but not much marble of this sort is available.

In the float near the mouths of the two creeks that flow into this cove, which drain mountain glaciers, there are many boulders of good white and veined marble, and in the canyon of the northern of the two creeks, at about a mile from the mouth of the creek (No. 5), an outcrop of fine-grained grayish-green, partly metamorphosed limestone 10 to 12 feet thick was observed.

Two islands in Glacier Bay, North Marble Island and South Marble Island, are composed wholly of marble, and others, such as Willoughby and Sturgess islands, show areas of limestone and marble. The two Marble islands lie about 12½ miles south of the entrance to Muir Inlet and are about 1½ miles apart. According to Coast and Geodetic Survey chart 8306 North Marble Island (No. 6) is about half a mile in length from north to south and less than a third of a mile in greatest width. The highest point is probably about 300 feet above the sea. The marble exposed in this island is yellowish to grayish and is stained along fracture planes. The rock is medium in grain and on weathered surfaces is generally soft and friable. Some portions of the rock are cherty; other portions are brecciated. According to T. N. Dale the grain diameter ranges from

0.05 to 1.05 millimeters but is mostly from 0.25 to 0.75 millimeter. The estimated average is 0.216 millimeter. The Rosiwal measurement gives an average of 0.00977 (about 0.01 inch, or 0.248 millimeter). The Vermont grade is 5 (coarse) and the texture is even.

Thin dikes of a dark fine-grained volcanic rock which appears to be altered spessartite cut the marble beds. The strike of the beds is nearly north. The rock has been jointed and in places shows small folds. The island has been glaciated, but weathering has been active and has produced through solution of material along joint planes and rounding of intermediate portions a bouldery appearance over much of the rock surface. Most of the rock is bare, but in crevices there is a thin cover consisting of mossy soil and vegetation, and hollows where loose material can find lodgment contain small quantities of glacial clay, gravel, and boulders. The island is surrounded by fairly deep water, but the shores are abrupt and afford no harbor.

South Marble Island (No. 7) is similar in character to North Marble Island but is a trifle longer, being about three-fifths of a mile in length. (See fig. 1.) The maximum width is less than half the length, and at one place the island is nearly cut in two at high tide. The maximum height probably does not exceed 250 feet. The marble here is mostly medium-grained white stone, although there is a little veined with gray and a little that is brecciated. A few small inclusions of fine-grained nonmetamorphosed limestone were noted. A thin section examined by T. N. Dale showed a range in grain diameter of 0.025 to 0.75 millimeter, mostly from 0.125 to 0.5 millimeter, with an estimated average of 0.146 millimeter. According to the Rosiwal method the grain diameter averages 0.0077 inch, or 0.196 millimeter. The texture is even, and very little pyrite was noted. The marble takes a good polish. The rock is cut by a few dikes of diabase ranging from less than 1 foot to 3 or 4 feet in thickness. The general strike is north. Joints cut the rock in several directions and are so numerous as probably to interfere with quarrying the marble at the surface. It is possible, however, that all of them may not extend to great depths. Part of the surface is bare and part is covered to a depth of a few inches to 3 feet with glacial débris supporting a growth of mossy turf and shrubs. There is some shoal water in the vicinity of South Marble Island.

Willoughby Island (No. 8) is in the western part of Glacier Bay, about 13 miles north of Icy Strait. It is about 4½ miles in length and 2 miles in width and reaches a height of nearly 1,600 feet. The south half of the island is composed mostly of gray limestone. At about the middle of the east side a small area of marble projects into the bay. This marble is medium grained, of cream and light-gray colors, and brecciated in places. Some patches of chert show on weathered surfaces. Mr. Dale finds that the grain diameter ranges from 0.112 to 2.8 millimeters, mostly 0.56 to 1.68 millimeters. The estimated average diameter is 0.56 millimeter. By the Rosiwal method the average grain diameter is 0.0181 inch, or about 0.46 millimeter. The grain form is uneven.

The marble is cut by dikes of greenish-gray micaceous, pyritiferous rock, probably dacite, and is jointed. In some places the joints are closely spaced, but in others there are masses of marble that show no joints for 20 to 30 feet. The gray brittle limestone south of the marble outcrop is closely fractured and jointed. The exposed marble extends for about 500 feet along the shore and rises to a height of 60 to 70 feet above the water. Near the shore the surface of the marble shows glacial grooves and striae. Back of the wave-washed exposure there is a growth of shrubs and small trees.

CHICHAGOF ISLAND.

The eastern shore of Chichagof Island from Peril Strait northward to Icy Strait is composed largely of Paleozoic rocks, including limestone, sandstone, phyllite, schists, and greenstone lavas and tuffs. Between Peril Strait and Point Augusta there is considerable limestone and some marble. The most promising deposits were noted in Tenakee Inlet and in Basket Bay and vicinity.

TENAKEE INLET.

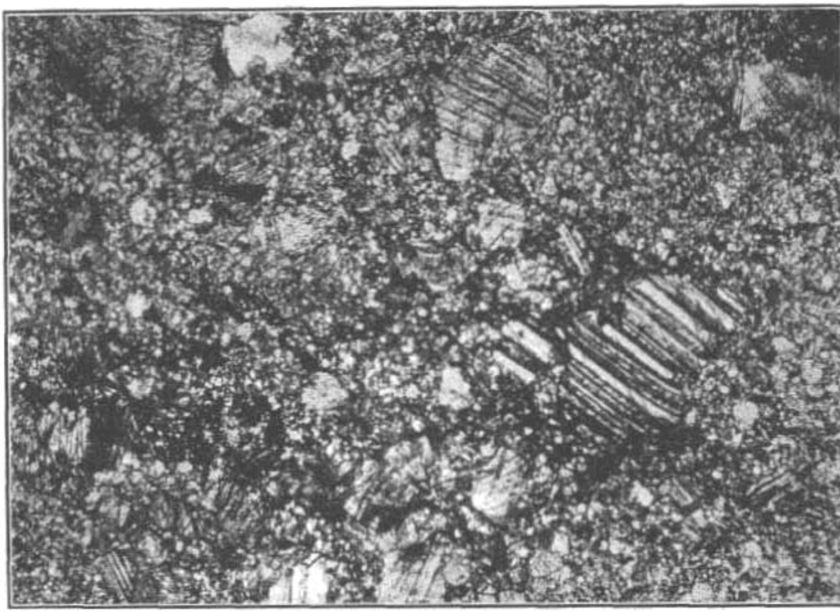
In the north side of Tenakee Inlet, from 1 to 2 miles east of Tenakee post office, marble is exposed at several places, in some of which it forms low bluffs 30 to 50 feet above the beach. On the banks of the large creek that flows into the inlet about a mile east of the village (No. 9), from a quarter to half a mile above the mouth of the creek, the marble forms low steep bluffs. Here it is coarse grained and much fractured, and some of it is schistose. The color is mostly nearly white, but some of the rock, especially the schistose parts, is white and green. This deposit was at one time located as a marble claim by persons sojourning at the Tenakee hot springs. On the beach, about 1½ to 2 miles east of Tenakee post office (No. 10), the marble exposed is brittle and hard and ranges from white to gray in color, some being gray and white banded, and there is also a little that shows mottlings of green and pink. It is generally of medium grain, but some, particularly the mottled stone, is fine grained. Specks of pyrite are present in places.

Mr. Dale examined microscopically two thin sections of the fine-grained marble from this area. One section, cut from a pale-yellowish-white specimen, showed a grain diameter of 0.02 to 0.14 millimeter, mostly 0.03 to 0.094 millimeter, and the estimated average is 0.04 millimeter. The Rosiwal measurement showed an average grain diameter of 0.0014 inch, or 0.0355 millimeter. This specimen is of even texture, but it contains streaks of pyrite in fine spherules and particles, roundish grains of feldspar and quartz reaching a diameter of 0.125 millimeter, and chlorite. The other specimen, which is white marble with faint yellowish bands, showed an abnormal texture, appearing to be a brecciated calcite marble with calcitic cement and to have been subjected to secondary compression. (See Pl. VI, *A*.) The groundmass of this specimen showed a grain diameter ranging from 0.0378 to 0.25 millimeter, mostly 0.047 to 0.14 millimeter, with an estimated average of 0.073 millimeter, and is to be classed as fine textured. The fragments disseminated in the groundmass are calcite plates having a grain diameter of 0.62 to 2.25 millimeters, with an estimated average of 0.89 millimeter, and are thus of coarse texture. The calcite of the groundmass is closely twinned, and the brecciated plates show curved twinning and retwinning produced by later movement.

The general strike of the rocks is northward, but the bedding is obscured by the folds and fractures, which are very prominent. The fractures are locally so close together that good hand samples can hardly be obtained from surface material. The marble is cut and impregnated by so much altered volcanic rock as to be in most places of little value, but it may be possible to find here and there material suitable for quarrying. Except where exposed on the beach and in stream cuttings the marble is concealed by a heavy forest growth.

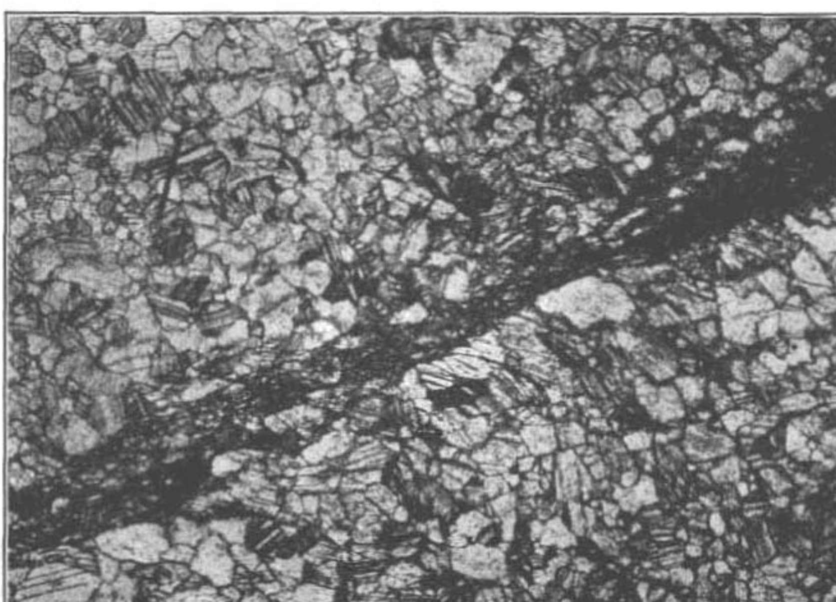
BASKET BAY AND VICINITY.

Basket Bay (No. 11) is a short, narrow arm of Chatham Strait about 8 miles south of Tenakee Inlet. Although only about a third of a mile wide and 1½ miles long, it affords good anchorage and good protection to vessels. The marble in the vicinity of Basket Bay is chiefly of fine grain. With reference to color there are four principal varieties—gray, gray and white banded, white, and dark blue with calcite streaks. On the southwest shore of the bay the marble is exposed almost continuously. Here the rock is massively bedded but weathers to thin spalls. The strike is N. 30° W., and the dip is steep toward the northeast. Myriads of small fractures cut the surface rock into small rhombohedral blocks, and the seamed condition extends up into the bluffs back of the bay. The marble is cut and impregnated in many places with seams of altered hornblende andesite. There is probably an enormous quantity of marble in this vicinity. The deposit on the southwest shore of Basket Bay appears to extend to the top of the 2,400-foot peak southwest of the bay. The appearance of the weathered summit and slopes of the 4,000-foot mountain to the northwest, 4 miles from the head of the bay, may be composed of limestone or marble, as it strongly suggests cal-



A. PHOTOMICROGRAPH OF THIN SECTION OF WHITE MARBLE FROM CHICHAGOF ISLAND, TENAKEE INLET.

View shows fine-grained groundmass containing coarser fragments of brecciated calcite with curved twinning. Magnified 10 diameters.



B. PHOTOMICROGRAPH OF THIN SECTION OF WHITE MARBLE WITH LIGHT-GRAY VEINS FROM TOKEEN.

The section is crossed by a band of very fine untwinned dolomite (?) along which shearing has taken place and shows also the uneven texture of the marble. Magnified 15 diameters.

A. SCHISTOSE MARBLE ON WAVE-SCOURED BEACH OF CHATHAM STRAIT, ADMIRALTY ISLAND, NORTH OF MARBLE COVE.

B. NEAR VIEW OF WAVE-SCOURED MARBLE ON BEACH OF CHATHAM STRAIT, CHICHAGOF ISLAND, SOUTH OF BASKET BAY.

ingly brought out on polished surfaces. The banding, the folds, and the flow structure are beautifully shown on the wave-scoured beach. Nowhere, however, is the marble for any considerable distance free from joints or from basaltic dike material. The bluffs are steep here and are surmounted with forests.

At a point on the north side of the small cove (No. 13), the marble is mostly fine grained and white, although there is a little interbedded light-gray rock. It is rather soft and friable above tide level in the cliffs, where it has been subjected to severe weathering, but it presents a handsome appearance. A thin section of the fine-grained white marble with faint green cloudings was examined by T. N. Dale, who found the grain diameter to range from 0.025 to 0.35 millimeter, but mostly from 0.125 to 0.25 millimeter, and estimated the average at 0.08 millimeter. The grade is a little finer than Vermont grade 2 (very fine). The texture is even.

The characteristic jointing, fracturing, and intrusion by dikes have affected the beds here in no less degree than in other places along this shore. At the head of the cove is exposed a fine-grained gray and white banded marble, which was traced three-quarters of a mile or more up the creek that empties into this cove. The beds are massive where unweathered, as, for instance, below high-tide level or below the level of the creek, but they show much fracturing where exposed to the weather. This condition suggests that the action of frost may have played an important part in opening fractures caused by strains. Flow structure and conspicuous folding are common. The whole mass seems to have been impregnated with thin dikes and stringers of hornblende andesite after the folding occurred.

In order to appraise the value of this interesting area of marble, considerable prospecting with the core drill will be necessary, trails must be cut into the interior, and the marble must be explored on the slopes of the mountains.

ADMIRALTY ISLAND.

The shores of Admiralty Island from Mansfield Peninsula to Chaik Bay and from Pybus Bay to the head of Seymour Canal are made up largely of limestone and schist. The general distribution of rocks along the shore line of this island is shown in Bulletin 287,[1] although slight modifications should be made as a result of observations during the study of marble deposits. For instance, the "Mar-

[1] Wright, C. W., A reconnaissance of Admiralty Island, Alaska: U. S. Geol. Survey Bull. 287, pp. 138–154, pl. 33, 1906. This bulletin is out of stock at the Survey but may be purchased from the Superintendent of Documents, Washington, D. C., for 75 cents.

ble Bluffs" on Chatham Strait, nearly opposite Tenakee Inlet on Chichagof Island, have been found to be composed of quartz monzonite, a light-colored granitic rock, instead of marble, as heretofore popularly supposed. In parts of the limestone belts the limestone has been metamorphosed to marble, some of which is of good quality and some of which is schistose. Exposures of marble were examined on the west shore between Cube Point and Point Hepburn, also south of "Marble Bluffs" and in Hood Bay, and search for marble was made at many intermediate points and in Pybus Bay.

POINT HEPBURN.

From 1 to 1½ miles north of Point Hepburn (No. 14) extends an area of medium to coarse grained schistose marble, which is white with gray, green, and black schistose bands. It includes nodules and lenses of fine-grained rock that probably contain magnesium carbonate. In places along the schistose planes pyrite is abundant. The rock occurs generally in beds 2 to 5 feet thick, but owing to the schistose structure it weathers to thin bands on the edges of the beds. The beds are cut by quartz veins and are interbedded with green schist.

Two samples of marble from this exposure were examined under the microscope by T. N. Dale and G. F. Loughlin. In one, a schistose green and white banded marble, the grain diameter ranged from 0.075 to 0.75 millimeter, mostly 0.25 to 0.5, with an estimated average of 0.187 millimeter. Much close twinning of the calcite is evident. The schistosity is shown in the section by the distribution of the grains of quartz and feldspar and scales of chlorite and muscovite, which form a series of bands. These bands contain also grains of titanite.

The other sample, a greenish marble, displays a very irregular texture. It consists of several small bands of fine and of coarse texture, some of them with epidote and hornblende and small grains of titanite, others with grains of feldspar and quartz, and some with large plates of calcite, one measuring 3 millimeters. In one of the coarser bands the quartz and calcite grains measure as much as 1.12 millimeters. The small beds are crossed at an angle of 25° by planes of slip cleavage. Much close twinning is present in the larger calcite grains. This is a calcite marble with quartz, feldspar, epidote, hornblende, and pyrite. The rock takes a fair polish, but owing to the presence of the schistose bands the polish is uneven.

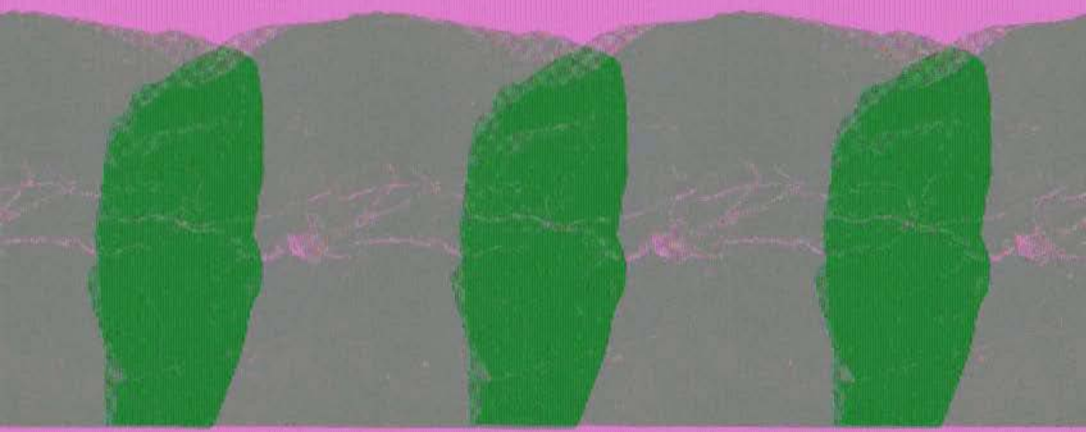
The beds strike N. 50° W. and stand almost vertical. There has been some close folding, but for the most part the bedding or schist planes are flat. This exposure now forms a low bluff for about half a mile along Chatham Strait, and the direction of strike carries the beds into a prominent ridge toward the southeast. On the beach the beds are not well situated for quarrying, as the bluff is steep and high tide reaches its base, but if the quality of the material should warrant exploitation, a quarry could probably be opened in the slope of the ridge and the product trammed to the cove near Point Hepburn, where anchorage for boats of medium draft is available.

MARBLE COVE AND VICINITY.

On Chatham Strait from a point 4 miles south of "Marble Bluffs" to a point 1 mile north of a small notch in the shore, which will here be called Marble Cove, there is a deposit of marble that possesses considerable scientific interest and possibly some commercial value. At this locality (No. 15) the marble is interbedded with bands of gray and green mica schist and white to gray variously banded quartz schist. The marble layers range from 1 inch to 3 or 4 feet in thickness. The bands of mica schist are generally 1 inch to 5 or 6 inches thick, and some of the bands of quartz schist are a little thicker but rarely exceed 1 foot. The marble is medium grained and is gray, white, pink, and green. All of it is susceptible of a fair polish, and the quartzite takes a glassy polish. The beds strike N. 60°–65° W. and are nearly vertical. They are cut by small dikes of dark-green hornblende dacite which send out stringers between the schistose layers. Folds are also exhibited by the varicolored bands. (See Pl. VIII, *A*.) This outcrop is exposed in a strip about 50 feet thick along the beach for a quarter of a mile or more and is partly submerged at high tide. (See Pl. VII, *A*.) It is bounded by a bluff which also contains alternate bands of marble and schist, the schist predominating. In strike with these beds, 1 to 1½ miles toward the southeast (No. 16), a similar body of banded marble, schist, and quartzite is exposed by a steep mountain stream.

Several thin sections of marble from this locality were examined by T. N. Dale and G. F. Loughlin. One section from a medium-grained white band in a schistose mass showed a grain diameter of 0.05 to 1.12 millimeters, mostly 0.12 to 0.62 millimeter, with an estimated average of 0.23 millimeter. The texture of this rock is uneven. Sparse grains of quartz, pyroxene, and tremolite were noted, also a few lenses of these minerals reaching 3 millimeters in length. The material is a slightly quartzose and pyroxenic calcite marble.

Another section showed medium-grained schistose material, with alterations of white and green bands. The white band consists of calcite having a grain diameter ranging from 0.075 to 0.62 millimeter, but mostly from 0.12 to 0.37 millimeter. The estimated average diameter is 0.166 millimeter. It has an uneven texture. The calcitic portion contains many particles and streaks of tremolite and pyroxene with a little quartz. On either side of the calcite band is a band of



epidote 0.1 inch wide. This rock is a calcite marble with pyroxene, epidote, tremolite, and quartz. In a section of the quartz schist the quartz grains form minute specks as much as 3 millimeters in diameter. The average grain, except in the coarse streak, is about 0.12 millimeter. Thin streaks of carbonate and augite give the schistose character. One band noted was composed chiefly of pale-green augite, 1 millimeter in maximum length but averaging 0.2 millimeter, rimmed in places by a little common hornblende. The other main constituent is quartz. A few grains of pyrite and titanite are present.

Another sample of medium-grained schistose material with white and green bands, but coarser than the material described in the preceding paragraph, shows a grain diameter of 0.125 to 1.37 millimeters, mostly 0.25 to 0.75 millimeter, with an estimated average diameter of 0.332 millimeter. The texture is uneven, the rock containing sparse pyroxene grains 0.05 to 0.37 millimeter in diameter. A central light-greenish band or vein averaging 0.1 inch in width crosses the section; it consists of green pyroxene with a little quartz and a very little pyrite. Minute specks of titanite are common. This band is crossed at right angles by numerous microscopic joints.

Still another section showed medium-grained greenish pyroxenic marble in which the grain diameter ranges from 0.074 to 1.3 millimeters, mostly 0.16 to 0.74 millimeter, and the estimated average is 0.24 millimeter. The texture is uneven and irregular. The calcite is closely twinned, and many of the grains have curved twinning, indicating secondary movement. The section contains sparse grains of pyroxene 0.17 to 1.5 millimeters in diameter, a few quartz grains, a quartz lens 1.25 millimeters long, and a little tremolite.

The wave-washed beach exposures of this banded rock afford some sections of very attractive material, and if it can be quarried advantageously it should be possible to obtain a large quantity of stone here that might be suitable for certain classes of interior decorative work. This rock, which consists of alternating layers of material of variant degrees of hardness, is not so easily sawed and polished as a more homogeneous rock. However, large blocks of similarly banded schistose marble found on Moira Sound, Prince of Wales Island, have been cut and polished and yielded very handsome finished slabs.

About a quarter of a mile to a third of a mile north of Marble Cove occurs another strip of attractive marble. The beds here also strike N. 60°–65° W. and stand nearly vertical. The total width (or thickness) of the exposure is 115 to 130 feet. It extends 500 to 600 feet along the beach and in places forms a bluff 40 feet high. From 40 to 50 feet of these beds at the northeast side consist of medium-grained gray marble, closely banded with thin dark-gray layers. The southwest 75 to 80 feet is coarse-grained yellowishent grades of texture. By micrometer measurement the finest-textured material has a grain diameter of 0.03 to 0.14 millimeter, with an estimated average of 0.05 millimeter. This fine material is shown on two opposite edges of the section. The next, by micrometer measurement, has a grain diameter of 0.1 to 0.25 millimeter, with an estimated average of 0.125 millimeter. The coarsest-textured material has a grain diameter of 0.15 to 1 millimeter, with an estimated average of 0.29 millimeter. Fine-grained streaks cut some of the large grains and are due to shearing about parallel to the bedding. This marble contains some weakly pleochroic white to pale-brown mica, mostly confined to short, discontinuous layers, and a few isolated flakes impregnating carbonate grains, probably nearer muscovite or phlogopite in composition than biotite, and a few tremolite grains. Some of the bands carry minute black particles, possibly oxidized pyrite or possibly graphite.

A section of the white marble shows a grain diameter of 0.28 to 1.40 millimeters, mostly 0.56 to 1.122 millimeters, with an estimated average of 0.466 millimeter. The section also shows a vein of calcite 0.56 millimeter thick, with streaks of fine and coarse grained calcite at right angles to this vein. The twinning is very close, and some of the grains are not transparent but clouded with dusty inclusions of carbon (?). An analysis by R. K. Bailey is as follows:

Analysis of white marble from deposit south of Marble Cove.

Insoluble matter	3.61
Calcium carbonate ($CaCO_3$)	95.44
Magnesium carbonate ($MgCO_3$)	1.45

A section of blue and white speckled marble taken from the beach near the diorite area on the south was examined by Messrs. Dale, Loughlin, and Mertie. The rock seems to consist partly of twinned dolomite and partly of twinned calcite. The grain diameter ranges from 0.12 to 1.5 millimeters, mostly 0.25 to 0.75 millimeter, with an estimated average of 0.35 millimeter. The grain is medium, and the texture is uneven. Scattered through the marble are fine to coarse dark specks which appear to be segregations of olivine altered to serpentine and magnetite. A little diopside is associated with the olivine. Mr. Mertie found also carbonaceous matter intimately mixed with forsterite and in places associated with sulphides. The hand specimen shows pyrite grains. An analysis of this rock by R. K. Bailey follows:

Analysis of blue and white speckled "marble" south of Marble Cove.

Loss on ignition	33.82
Insoluble matter (SiO_2 and R_2O_3)	9.71
Calcium oxide (CaO)	33.60
Magnesium oxide (MgO)	19.08

Adjoining this deposit on the south is an area of altered quartz diorite, shown on Plate XXXIII of Bulletin 287 as extending southward nearly to Parker Point. In the area extending southward from Parker Point to Chaik Bay schist predominates and no desirable marble was noted except at Hood Bay.

Wright[1] states that certain parts of the limestone belts on the west coast of Admiralty Island, mapped during his reconnaissance, have been converted into marble, some of which is sufficiently massive and even grained to make an excellent building stone, though, perhaps, not fit for ornamental purposes, but that large slabs or columns probably can not be obtained owing to the system of joints. Referring to the areas between Point Hepburn and Marble Cove, he states that a mass of marble forms the rock on the west shore opposite Tenakee Inlet for a distance of 8 miles and, being easily accessible, may prove to be of economic value. According to Wright, the marble contains bands rich in dolomite, has a fine granular texture, a white to light-gray color, and in places a banded appearance. The studies of the writer have shown that this marble area is not continuous but is interrupted by areas of monzonite, diorite, and schist; that much of the marble is schistose, which probably accounts for the banded appearance mentioned by Wright; and that the deposit contains much coarse-grained as well as fine-grained marble.

HOOD BAY.

Some fine-grained white marble was noted in two places on the northeast shore of Hood Bay (No. 18), almost due east of Distant Point. In hand samples this is a very beautiful marble, which takes a good polish, but its availability in large blocks and in large quantity is questionable. Mr. Dale finds that the grain diameter of this marble ranges between 0.05 and 0.3 millimeter but mostly between 0.125 and 0.2, and estimates the average at 0.091 millimeter. The grade is thus a trifle finer than 2 (very fine). The texture appears even. Mr. Dale mentions the presence of grains of quartz and feldspar from 0.037 to 0.148 millimeter in diameter, but these were not recognized by Mr. Loughlin.

The marble is associated with schist and becomes schistose in the direction of the strike, which is apparently N. 70° E. The beds are rather slabby and dip about 20° SE., although the angle of dip is variant. The surface rock is jointed into small rectangles, a few inches to 2 or 3 feet across. Veins and eyes of quartz were noted in the marble. One of the exposures measured about 500 feet between its borders of schist and possibly 100 feet on the strike, between mean

[1] Wright, C. W., A reconnaissance of Admiralty Island, Alaska: U. S. Geol. Survey Bull. 287, p. 154, 1906.

tide level and the wooded bluff. The rock farther up the hill was found to have a schistose texture. At the other exposure, about a quarter of a mile to the southeast, the material is similar in character but has been much fractured and carries considerable quartz in eyes and veins.

CHAIK, PYBUS, AND GAMBIER BAYS.

Wright[1] states that small belts of marble occur at Chaik Bay, on the west side of the island, and at Gambier and Pybus bays, on the southwest side. Neither Chaik Bay nor Gambier Bay was examined by the writer. On the west side of Pybus Bay, about 2½ miles from the entrance, is a small area of gray crystalline limestone with bands and nodules of chert. The beds strike north and dip 72° E. At the end of a small point where the beds are exposed they are thin and much fractured, but in an overhanging cliff facing a small cove they appear to be more massive. These beds are abundantly fossiliferous, and in the cliff the fossils appear in relief on the weathered faces of the beds. A collection of these fossils made by the writer contained the following species, as determined by George H. Girty, who states that they are supposed to be of Artinskian age, or well along in the Carboniferous:

Lot 38. Fossils from west side of Pybus Bay, 1913:
- Batostomella sp.
- Camarophoria aff. C. margaritovi.
- Chonetes aff. C. morahensis.
- Productus aff. P. timanicus.
- Productus aff. P. gruenewaldti.
- Productus semireticulatus.
- Productus aff. P. multistriatus.
- Productus sp.
- Tegulifera? sp.
- Dielasma sp.
- Rhynchopora aff. R. nikitini.
- Spirifer aff. S. cameratus.
- Spiriferella? arctica.
- Squamularia aff. S. perplexa.
- Modiola? sp.
- Murchisonia? sp.

At several points on the west side and on the east side near the head of Pybus Bay is exposed a much fractured cherty magnesian limestone containing crinoid stems and small brachiopods. The shore line of Pybus Bay, except at the mouth of the bay, is mapped by Wright[2] as limestone and schist, but by far the greater part of the west shore line is made up of a dark metamorphosed shale. This

[1] Wright, C. W., op. cit., p. 154. [2] Idem, pl. 33.

dark rock is regarded by Edwin Kirk as of Triassic age. No rock that could be termed commercial marble was discovered in Pybus Bay.

KUPREANOF ISLAND.

Beds of limestone interstratified with schist have been noted on Kupreanof Island on the west side of Duncan Canal. Among the Castle Islands beds or lenses of cherty limestone containing veins of calcite were noted by the writer to be nearly in strike with a lens of barite,[1] with relations suggesting that the barite may have been formed through the replacement of limestone. In the autumn of 1914 W. C. Waters forwarded to the Survey samples of partly metamorphosed light and dark grayish-blue limestone with bands and patches of white calcite from the north side of the west arm of Duncan Canal and light-gray finely laminated marble from the south side of the west arm of Duncan Canal. Although the charts of the Coast and Geodetic Survey do not show which is the "west arm" of Duncan Canal, it is believed that this arm is the shallow one that joins the main body of water about 4 miles south of the Castle Islands, and it is therefore indicated as locality 19 on the accompanying index map (Pl. I). The grain of the samples from the north side of the arm is irregular, ranging from moderately fine in the mass to moderately coarse in the calcite streaks. The light grayish-blue sample from the south shore is medium and more even grained but shows numerous coarser calcite crystals and a few specks of pyrite. According to Mr. Waters these deposits are exposed along the beach for about 1½ miles and lie about 2 miles from deep water. The rock strikes northwest and dips about 45° SW. The associated beds are shale and schist, and the overburden consists of 6 to 8 feet of moss and soil. The limestone and marble are themselves schistose, and the samples submitted appear to be of no particular merit, but the occurrence is noted here in the hope that it may lead to further and better discoveries in this locality, which is centrally situated and near steamship routes.

NORTHERN PART OF PRINCE OF WALES ISLAND.

POINT COLPOYS.

Much of the northern shore line of Prince of Wales Island facing Sumner Strait is formed by fine-grained to dense bluish-gray limestone, more or less metamorphosed and cut and impregnated by igneous rock. West of Point Colpoys is an area of marble (No. 20) that has appeared sufficiently attractive to the prospectors, Woodbridge & Lowery, to warrant them in staking out claims. The mar-

[1] Burchard, E. F., A barite deposit near Wrangell, Alaska: U. S. Geol. Survey Bull. 592, pp. 109–117, 1914 (Bull. 592–D).

ble is fine grained and comprises mottled and white varieties, the mottled greatly predominating. Reddish stains along fracture planes give to some portions of the marble an attractive appearance. Some of the marble is brecciated and conglomeratic, with white and red contrasts. The bedding is indistinct, and the rock is closely fractured and jointed on the beach exposures. Numerous thin dikes of altered olivine basalt cut the deposit in several directions; the most prominent system of dikes strikes about N. 40° W. This deposit is exposed along the beach for a quarter of a mile or more and extends back into the interior an undetermined distance. The quantity of the marble available is probably small, and it is likely that owing to the multitude of intersecting dikes and fractures no large blocks can be obtained. This portion of Prince of Wales Island near the shore is low and is covered with a swampy forest growth.

Another group of claims owned by Woodbridge & Lowery lies about 2 miles west of Point Colpoys (No. 21, Pls. I and III). The rock here is fine-grained limestone, only slightly if at all metamorphosed. It is all much brecciated and displays a variety of colors, including white, red, gray, and black. Fractures and joints are very numerous, and the rock is cut by many dikes which have been faulted and contorted. The exposure extends along the beach for one-third mile or more, but is obscured inland by a heavy forest growth.

RED BAY.

At the east side of the entrance to Red Bay, along the west shore of Bells Island, fine-grained slightly metamorphosed limestone is exposed for about half a mile (No. 22). Below high-tide level this stone is generally light colored on fresh surfaces, with white and pink mottled effects predominating; above high-tide level darker colors, such as grays and blues, predominate. Some handsome mottled and brecciated material is present here. The deposit is badly fractured and is intersected closely by dikes of andesitic and basaltic rock. Woodbridge & Lowery have located a claim extending 1,500 feet along the shore and 600 feet inland known as the East Side claim. There is a heavy growth of forest and underbrush above tide level.

Marble appears also on the west shore of Red Bay about 2½ miles from the mouth, near the head of the bay, and beyond in the vicinity of Red Bay Mountain.

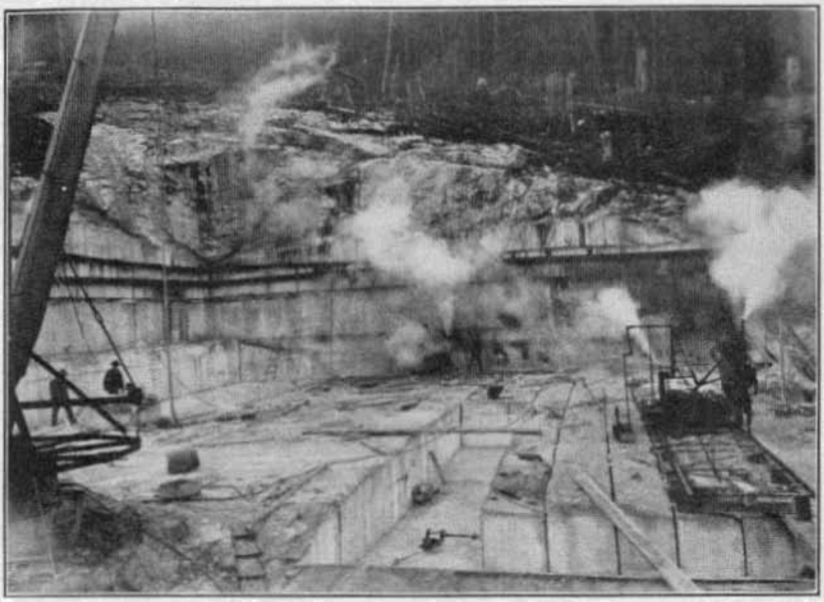
The marble on the west shore of Red Bay (No. 23) is fine grained and is mostly light colored, showing white, faintly to strongly clouded gray, and grayish-blue shades. The part exposed at the surface is rather soft. The beds are cut by several dikes of metadiabase, most of which are only a few inches thick, though one measuring 4 to 6 feet was noted. Thin irregular stringers from some of these dikes penetrate the marble in all directions. The marble exposed on the beach is jointed and, where weathered, shows slightly schistose planes that strike north-northeast. One bed of partly metamorphosed dark-bluish limestone, much fractured and having the seams filled with calcite, was noted interbedded with the marble.

On account of the softness of the samples, which were of necessity taken from the water-soaked surface, it was difficult to make thin sections of this marble. Two sections, both light colored, fine grained, and more or less fragmentary, were examined by T. N. Dale. One section showed a grain diameter of 0.02 to 0.141 millimeter, with some exceptionally large particles, but mostly between 0.047 and 0.094 millimeter. The texture is uneven. The Rosiwal measurements showed an average grain diameter of 0.001755 inch, or 0.04457 millimeter. The other section shows a grain diameter ranging between 0.02 and 0.2 millimeter, but mostly between 0.03 and 0.094 millimeter, and the estimated average diameter is 0.05 millimeter.

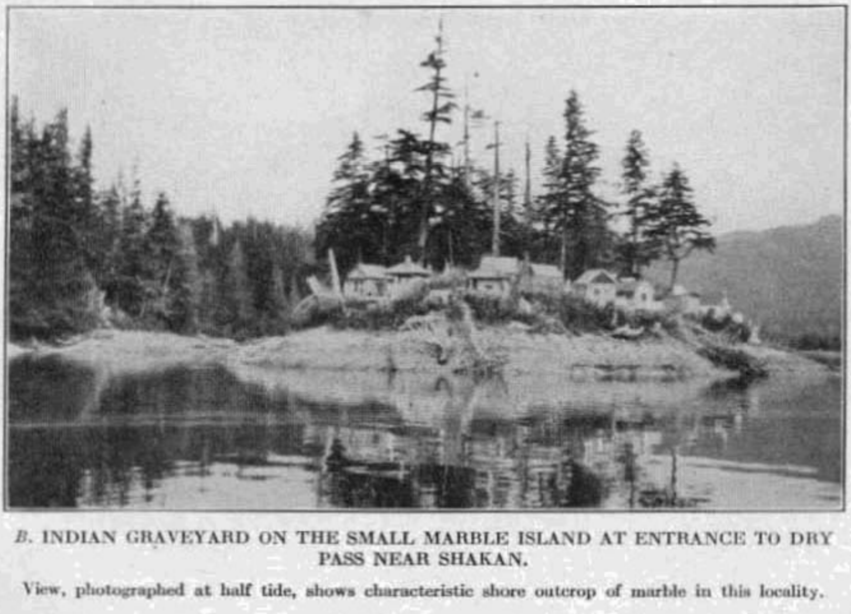
Claims aggregating 80 acres, extending about half a mile parallel to the beach and one-fourth mile inland, were located on this deposit by Woodbridge & Lowery. In 1912 some prospecting was done on the beach by hand and by blasting with black powder, and back of the beach, within the woods, the soil was stripped off and the surface of the marble was bared in several pits and trenches, some of which are 140 feet long. The cover is 2 to 4 feet or more thick. It is reported that in 1915 the Vermont Marble Co. opened a quarry on these claims about a quarter of a mile back from the beach. The marble is said to be cream-colored with rust-colored veins, like the Grecian Skyros marble. The beds are reported to stand vertical and to be much fractured, so that the blocks obtainable are relatively small.

On the west shore of Red Bay about three-quarters of a mile south of the Woodbridge & Lowery claims and separated from them by a body of dark intrusive rock is an exposure of fine-grained light-gray to dark-gray marble. Samples from an exposure in the woods about 500 feet back from the beach and 60 to 80 feet above high-tide level are mottled. The weathered marble on the beach is very soft and appears slightly schistose, with the gray veins parallel to the schistosity.

At the head of Red Bay and above the head of the bay, between Red Bay Mountain and the head of a small lake about 1½ miles long which lies south of the bay, there are deposits of marble (Nos. 24 and 25) on which the Vermont Marble Co. has located claims. It is probable that this belt of marble extends southwestward nearly if not quite to Dry Pass. The mass of marble at Winter Harbor has been traced a mile or more northeastward from Dry Pass.



A. MARBLE QUARRY OF ALASKA MARBLE CO. AT CALDER, PRINCE OF WALES ISLAND.



B. INDIAN GRAVEYARD ON THE SMALL MARBLE ISLAND AT ENTRANCE TO DRY PASS NEAR SHAKAN.

View, photographed at half tide, shows characteristic shore outcrop of marble in this locality.

The deposit at the head of the bay (No. 24) has been tested by drill holes near Little Creek and on the left bank of a small creek between Little Creek and Big Creek. About 25 feet of a ⅞-inch core was noted at the latter place in September, 1913, and a small area of perhaps 10 square yards of the surface rock had been exposed by stripping. The marble is white with gray veins, of medium grain, and rather soft, so far as shown by the exposure and the core. The drill hole intersected a 1¼-inch dike of hornblende andesite(?) containing pyrites. Mr. Dale finds that the grain diameter of the marble ranges from 0.074 to 0.925 millimeter, mostly 0.148 to 0.555 millimeter, and estimates the average to be 0.216 millimeter. The Rosiwal measurement gave an average grain diameter of 0.0079 inch, or 0.2 millimeter. The texture is uneven. The marble is covered by a heavy mold and forest growth. It lies at a distance of a mile or more from deep water, as the upper end of Red Bay consists of mud flats at low tide.

On the southeast shore of the bay near the head, facing the mud flats, are exposures of hard fine-grained subcrystalline, partly metamorphosed limestone of light-gray and cream colors with mottled effects and also showing banded gray and blue phases. A thin section of this limestone was found by Mr. Dale to be composed of polarizing untwinned grains of calcite from 0.004 to 0.043 millimeter in diameter with a few lenses of twinned calcite grains. This rock is cut by andesite dikes and more or less fractured. In order to ascertain whether this rock was limestone or dolomite the following determinations were made by R. K. Bailey:

Analysis of limestone from head of Red Bay.

Insoluble matter	1.70
Calcium carbonate ($CaCO_3$)	96.90
Magnesium carbonate ($MgCO_3$)	2.59

PORT PROTECTION.

About a quarter of a mile southeast of the head of Port Protection and 1 mile from deep water (No. 26), a mass of limestone forms a divide between two small creeks that flow into the bay. This limestone forms a bluff about 100 feet in height with nearly vertical bedding and a northwesterly strike. The rock consists chiefly of fine-grained gray to nearly white stone, in places partly metamorphosed to marble. It is badly jointed and fractured at the surface and is veined and discolored, especially along the fracture planes.

SHAKAN BAY.

Marble and limestone beds border the northeast shore of Shakan Bay, and the marble is well exposed in the entrance to Dry Pass in two small islands, on which are Indian graveyards (Pl. IX, *B*).

This marble is now considered to be of Silurian age and to have been altered by the intrusion of a granite mass that lies adjacent to it on the southeast. Claims 2 miles long and half a mile or more wide were located along the coast of Shakan Bay (see fig. 2) in 1905 by the Alaska Marble Co., after considerable prospecting by trenching and drilling to ascertain the extent of the marble and its quality in depth. A quarry has been opened near Calder, at an altitude of

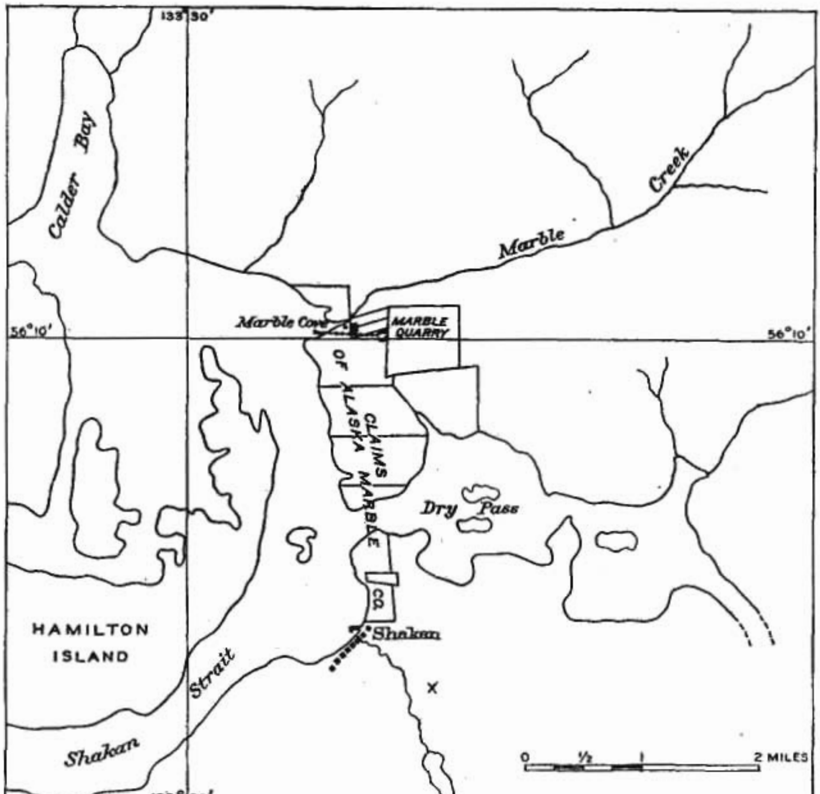


FIGURE 2.—Sketch map showing marble quarry and claims of Alaska Marble Co. on Prince of Wales Island, Shakan Bay.

about 100 feet on the hillside south of Marble Creek, about half a mile above its mouth (No. 27), and an area of 100 by 200 feet has been stripped and quarried to a depth of nearly 100 feet measured on the hillside, about 60 feet below the level of the tramway. (See Pl. IX, *A*.) A tunnel has also been driven back for a distance of about 25 feet at the southeast corner of the quarry pit.

The quarry is connected with deep water in Marble Cove by an inclined trestle, 3,200 feet in length, on which is laid a standard-gage railroad track. Loaded cars run down to the wharf by gravity and are drawn back to the quarry by cable. The wharf is equipped with a stiff-leg derrick, and the quarry with two derricks, necessary channeling and gadding machines, and a complete machine shop. The power plant near the quarry which operates the quarry derricks and the tramway cable is equipped with an 80-horsepower boiler. A small engine on the wharf operates the derrick there.

The character and relations of the marble deposit are described as follows by the Wrights,[1] who visited this locality while active work was in progress:

The extent of the marble deposit at this locality has been investigated at a number of points on the surface by open cuts and trenches and in depth by eighteen drill holes, and at all of these places marble usually of good quality is exposed. The marble belt is approximately 3,000 feet in width, striking in a nothwesterly direction and dipping to the southwest. It is limited on the northeast by an intrusive granite mass and on the southwest by the shore line. To the south it crosses the entrance to Dry Pass, but just back of Shakan it is cut off by a granite mass, while to the northwest it extends into the channel and reappears at the entrance to Calder Bay, extending northward and overlying beds of conglomerate. Along the shore exposures and at the quarry small dikes of diabase, striking northeasterly and much altered and faulted, were observed intersecting the marble beds. Apparently these dikes antedate the metamorphism of the limestone and therefore the intrusion of the granite. They are, however, but a foot or two in width and not sufficiently numerous to affect the value or expense of quarrying the marble. In the present opening at the quarry only one dike is exposed. Both surface cracks and slipping planes are present in the surface exposures of the marble, but in depth these are less numerous and will not materially interfere with quarrying.

Three distinct varieties of marble are found—pure white, blue-veined with white background, and light blue, often having a mottled appearance. The pure white, which has a finely crystalline texture, is the most valuable. All of the marble is free from silica and flint beds common in most quarries and though thin seams of pyrite were observed they do not occur in a quantity detrimental to the stone. The following chemical analysis of the white marble was made by E. F. Lass for the Alaska Marble Co.:

Chemical analysis of white marble from Marble Creek, Prince of Wales Island, Alaska.

Insoluble matter	0
Oxide of iron (Fe_2O_3)	Slight trace.
Sulphuric anhydride (SO_3)	Trace.
Lime (CaO)	55.59
Magnesia (MgO)	.30
Carbon dioxide (CO_2)	43.67
Undetermined	.44
	100.00
Calcium carbonate ($CaCO_3$)	99.26

A qualitative test for magnesia in a sample collected by the writers was made by Dr. George Steiger, of the United States Geological Survey, who reports a content of less than 1 per cent.

[1] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 194–195, 1908.

To determine the crushing strength of the stone the Alaska Marble Co. submitted samples to N. H. Winchell, State geologist of Minnesota, who reports an average strength of 10,521 pounds per square inch, a strength ample for all building purposes. Though not equal to the best Italian grades this marble is better than most American marbles and in the market will compete on at least equal terms with the product of Vermont, Georgia, and Tennessee.

A thin section of the white marble from Calder, examined by T. N. Dale, showed a grain diameter of 0.075 to 0.625 millimeter, mostly 0.125 to 0.375. The Rosiwal measurements gave an average grain diameter of 0.0058 inch, or 0.147 millimeter. The grade is medium, and the texture is uneven.

A thin dike of metabasalt at this quarry contains much pyrite and a streak of pyrrhotite.

Experience in quarrying this marble seems to have shown that the whiter varieties are softer than the veined or clouded varieties. Areas in which the rock is too soft for commercial purposes are not uncommon, even in the depths of the quarry. The marble beds are much fractured, and as yet the fractures have not been found to disappear entirely with increasing depth. A vertical hole is reported to have been bored with a core drill 175 feet below the present bottom of the quarry, and two more holes were drilled in the southeast and southwest corners of the quarry for distances of about 200 feet at an angle of about 45° to the horizontal. All these cores are reported to have shown marble of good quality.

Shipments of marble were made from this quarry each year from 1906 to 1910, but no quarrying has been done since December, 1909. The product in rough blocks was shipped mostly to a sawing and polishing plant at Tacoma, Wash., where it was prepared for interior decoration. Shipments were also made to Spokane and San Francisco and to several eastern cities. The closing of the quarry may have been due to failure to find sufficiently hard stone within the depths quarried. According to recent reports, it is planned to reopen this quarry whenever the conditions of finance and the markets will warrant it. Some development work is reported to have been done at Calder in 1915, and some prospect drilling on Dry Pass near the Indian burying ground yielded good white cores. The equipment generally has been kept in good condition.

DRY PASS.

The marble area extends eastward from Calder about 2 miles along the north side of Dry Pass to a small shallow cove known locally as Winter Harbor, just east of the shallowest part of Dry Pass, where it terminates against a mass of gray granite. The marble in this vicinity is white and gray to light grayish blue in color and is coarsely crystalline near the contact with the granite. On the surface it is not very hard and is easily disintegrated to sand by water running down the slopes. On the northeast shore of the small cove the marble forms low cliffs, over one of which, at the north end of the cove, falls a small mountain stream. Half a mile above the mouth of this creek a cliff of gray coarsely crystalline marble 100 feet high (No. 28) surmounts a talus slope about 200 feet high, which extends from the creek to the cliff. The top of the marble cliff is probably 500 feet above sea level. The general trend of the ridge is N. 60° E., and the marble mass may be continuous with the deposits located by the Vermont Marble Co. south of Red Bay. Between Winter Harbor and Shakan Bay the marble beds are cut by several dikes and are intruded by small areas of basaltic rock.

Thin sections of the white marble near the cove and of the light-gray marble from the cliff half a mile from the shore were examined by T. N. Dale. Both are coarse grained. In the white marble the grain diameter ranges between 0.56 and 4.48 millimeters, but mostly between 1.40 and 2.80 millimeters. Measurements according to the Rosiwal method showed an average grain diameter of 0.049 inch, or 1.24 millimeters, and the texture is fairly even. In the light-gray marble the grain diameter ranges between 0.28 and 2.80 millimeters, mostly 0.56 to 1.96 millimeters. The Rosiwal measurements showed an average grain diameter of 0.0331 inch or 0.84 millimeter, and the texture is uneven.

Marble as coarse as this seldom shows as great strength as fine-grained marble and is likely to show greater porosity and absorption, yet if normally sound stone can be obtained its strength will doubtless be found ample for all interior decorative work for which the marble would be suitable, and probably also for exterior walls of small buildings. Certain Georgia marbles that have been largely used for decorative purposes resemble the gray rock in color and texture.

EL CAPITAN.

On the north side of Dry Pass, about 2½ miles east of Winter Harbor, east of the granite mass just mentioned, marble beds (No. 29) form the surface rocks for a mile or more. Ten marble claims located here were acquired by the El Capitan Marble Co., in 1903. In 1904 a small quarry pit 12 feet deep was opened near tidewater by channeling and gadding machines, and 3 gangsaws operated by steam power were installed. A small quantity of marble was shipped to Seattle. Operations were suspended at the end of 1904 and have not been resumed, although the property has been cared for, and it is rumored that the quarry will be reopened. Drilling operations were under way in the summer of 1917.

The marble exposed in the El Capitan quarry is of medium grain and not very hard. It is of slightly coarser texture and shows more contrast than the marble at Calder. The color is white with faint gray veins and cloudy areas. The exposures near the beach are badly fractured. In one set of fractures, which strikes N. 60° E., nearly all the openings are filled with quartz, which stands out in relief on the weathered surfaces. These quartz seams are nearly vertical and are spaced from 3 or 4 inches to many feet apart. A small geode of quartz crystals was noted in the marble exposed in the wall of the quarry pit. The presence of siliceous material in the marble may render the stone slightly difficult to saw uniformly. Several metadiabase dikes cut the marble beds. Near the quarry one dike which is much jointed and has been faulted and deformed ranges from 12 to 18 inches in thickness, strikes N. 40° E., and dips steeply southeast. Wright considers that the dikes were intruded and later disturbed, all, however, prior to the metamorphism of the limestone beds.

In the bluffs northeast of the El Capitan quarry at 200 to 400 feet above sea level are exposures of medium-grained light-blue marble which has been prospected by pits and trenches, and about half a mile above the mouth of a small creek that empties near the sawing plant are exposures of fine to medium grained white marble, all of which are included within the El Capitan group of claims.

Three thin sections of these marbles were examined by T. N. Dale. A section of the marble from the quarry opening showed an uneven texture and proved to have a grain diameter ranging from 0.05 to 0.75 millimeter, but mostly between 0.125 to 0.5 millimeter. Rosiwal measurements showed an average grain diameter of 0.0059 inch, or 0.15 millimeter. A section of the white marble exposed half a mile up the creek above the sawing plant showed a grain diameter of 0.05 to 0.5 millimeter, mostly from 0.07 to 0.25 millimeter, with an estimated average diameter of 0.125 millimeter, indicating that the grain is medium. The texture is even. A section of another specimen of white marble from the same deposit showed a grain diameter of 0.05 to 0.375 millimeter, mostly between 0.125 and 0.5 millimeter. The texture is uneven. Rosiwal measurements showed an average grain diameter of 0.0052 inch, or 0.132 millimeter.

KOSCIUSKO ISLAND.

On Kosciusko Island, on the opposite side of the channel from the El Capitan marble claims, are exposures of marble (No. 30), most of which is grayish, although some is nearly white. This marble is rather fine grained and is cut by fractures filled by siliceous seams like those on the El Capitan property. These seams are one-sixteenth to one-fourth inch thick, are spaced from 4 inches to 4 feet apart, strike N. 50° E., and are nearly vertical. According to practical marble men the presence of quartz seams in such abundance as these renders the marble of very doubtful commercial value. Toward the east and south along this shore of Kosciusko Island the marble gradually merges into less metamorphosed limestone. At Aneskett Point the rock is a dense fine-grained limestone, much fractured and seamed with calcite.

In the eastern part of Kosciusko Island, between the southwest base of Pyramid Peak and the head of Tokeen Bay, three claims of 160 acres each (No. 31) have been located by the Vermont Marble Co. The marble here lies south of the granitic mass that is believed to have produced the metamorphism of the marble deposits of Calder and the El Capitan claim farther north. The deposit is exposed for about 200 feet in a steeply sloping bluff 20 to 30 feet high on the left bank of a small mountain creek that flows southwestward into Tokeen Bay about half a mile distant. At the lower end of the exposure the marble is dark bluish gray and fine grained, but the greater part of the deposit is medium grained and white and is thinly veined with dark-gray or yellowish seams. On the exposed face the marble is very soft and crumbly, almost saccharoidal, and it was difficult to obtain a sample firm enough to be carried away. The beds are cut by numerous joint planes. Prospecting has been done by blasting and by core drilling nearly at right angles to the face, which seems to represent a steep dip slope. The prospects are about 200 feet above sea level. To transport the marble to tidewater it would be necessary to build one-half to three-fourths of a mile of tramway through some rather rough country.

On the southeast shore of Kosciusko Island northeast of Edna Bay outcrops of dull to dark gray limestone alternate with narrow areas of graywacke for 2 miles or more. The limestone is cut by basaltic dikes and is everywhere badly cracked. At the contact with some dikes it is locally metamorphosed to marble, but the marble thus produced is probably not of uniform quality nor of sufficient extent to be of commercial value. On the shore 3 or 4 miles northeast of Edna Bay a small area of fine-grained red and white mottled limestone was noted, and a short distance inland, along a small stream (No. 32), occurs an area of fine-grained variegated marble in which stone of yellow, sienna, and red shades predominates. This is the same bed as the variegated limestone on the north side of Heceta Island (p. 76). Claims have been located in this area by W. C. Waters, of Wrangell, Alaska, and have been extensively prospected by the Vermont Marble Co.

A sample of brecciated fine-grained green limestone, seamed by veins of pink calcite, was sent to the Survey by W. C. Waters in the winter of 1915 from Kosciusko Island, "7 miles from Holbrook," probably in a southwest direction, which places it near locality 32. The green limestone is more or less mottled by dark and light green fragments, which, together with the pink veins, would probably produce a handsome effect in a polished surface. The rock shows slickensides, is very brittle, and breaks rather easily; therefore it might be difficult to work into large slabs. Mr. Waters states that the rock strikes northwest and extends over an area 100 by 300 feet; that the covering is moss, timber, and brush; and that the formations with which the green rock is associated are limestone and conglomerate.

Another interesting sample sent by Mr. Waters is a conglomerate of fine-grained light-gray limestone pebbles in a pink calcareous matrix cut by thin veins of yellowish calcite filling fault fissures. This rock is a little harder than the breccia described above and would undoubtedly polish well and produce a handsome effect. It is not known whether large blocks are available. The locality is given as Kosciusko Island, "6 miles from Holbrook," the observed extent of the material as 400 feet by a quarter of a mile, and the cover as moss, brush, and timber. The associated formation is reported to be limestone striking northwest.

MARBLE AND ORR ISLANDS.

GENERAL FEATURES.

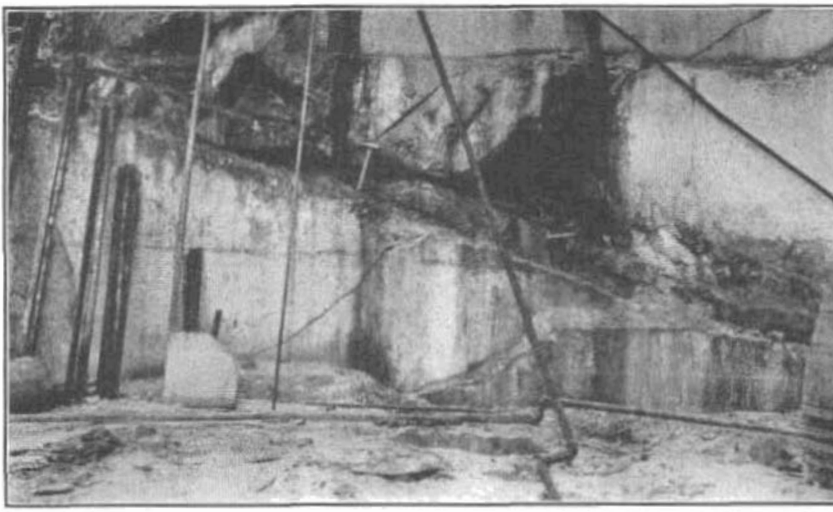
The most extensive developments of marble in southeastern Alaska are in the northwestern part of Marble Island, one of the larger islands in Davidson Inlet, on which marble was first discovered in 1899. Quarrying has also been begun on Orr Island, just across the narrow inlet from Marble Island.

Marble Island extends about 3 miles from east to west and about 4 miles from north to south. Its surface is densely wooded and is generally of moderate relief, the highest point noted by the Coast and Geodetic Survey being 1,528 feet above sea level. According to the Wrights[1] the rocks of both Marble and Orr islands are classified as limestone and other sedimentary rocks, together with schists and volcanic tuffs, all of Paleozoic age. Much of the limestone in this area has been metamorphosed to a high-grade marble.

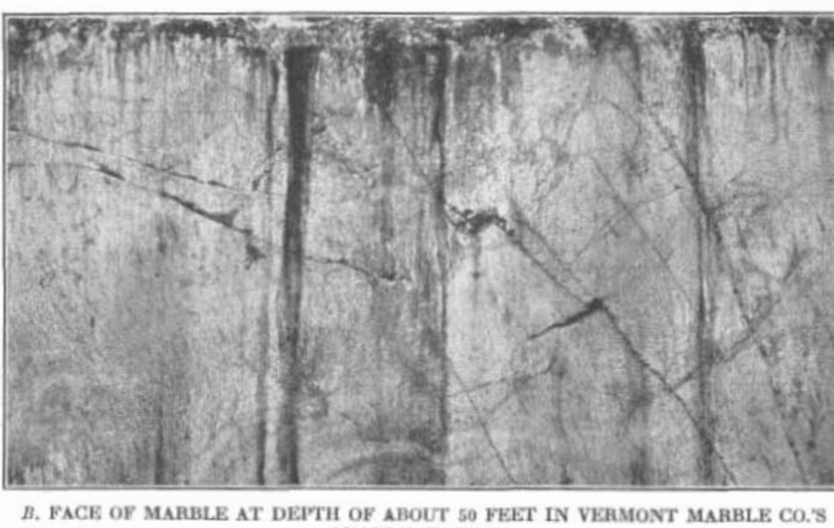
VERMONT MARBLE CO.'S PROPERTIES.

Certain marble claims that were located in the northwestern part of Marble Island in 1903 have been purchased by the Vermont Marble Co., which has opened large quarries (No. 33) and built a small village named Tokeen. The total area held by the company aggregates 703¼ acres, according to the plat of mineral survey

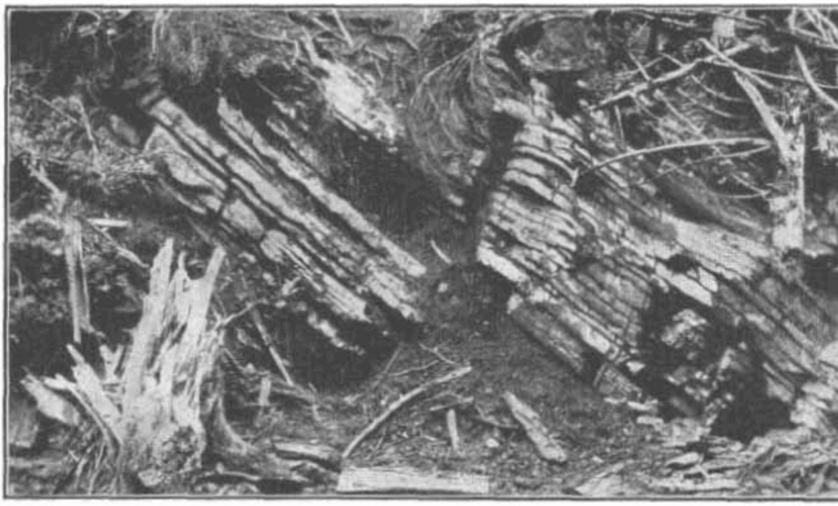
[1] Wright, F. E. and C. W., op. cit., pl. 1.



A. ANDESITE PORPHYRY DIKE ABOUT 1 FOOT THICK CUTTING MARBLE BEDS ON WEST SIDE OF VERMONT MARBLE CO.'S QUARRY, TOKEEN.



B. FACE OF MARBLE AT DEPTH OF ABOUT 50 FEET IN VERMONT MARBLE CO.'S QUARRY, TOKEEN.



A. FOSSILIFEROUS BLUE-BLACK LIMESTONE BEDS IN TRAMWAY CUT 250 FEET FROM THE WHARF, TOKEEN.

B. STRIPPING OPERATIONS OF VERMONT MARBLE CO., SHOWING SURFACE OF WEATHERED MARBLE, TOKEEN.

No. 927, made by L. D. Ryus, deputy mineral surveyor of Ketchikan. (See fig. 3.)

Blue-black limestone.—The marble in the main quarry is massive and has yielded no fossils except crinoid buttons, but it overlies thin-bedded blue-black limestone which has yielded fossils of probable Silurian age, consisting of *Merestina* sp., *Clarinda* sp., *Conocardium* sp., *Trochonema* sp., *Favosites* sp., and *Cyclonema* sp., as determined by Edwin Kirk, of the United States Geological Survey.

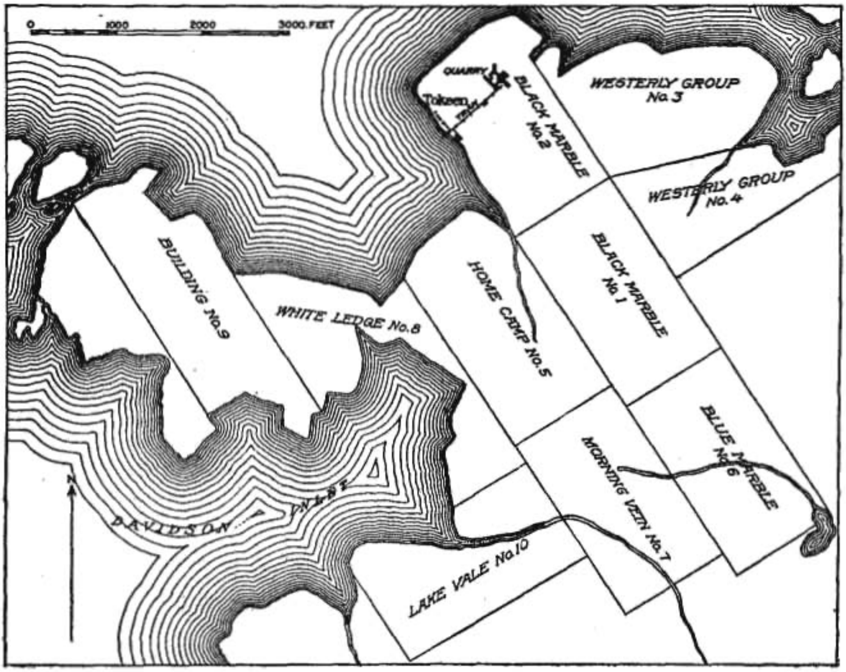


FIGURE 3.—Sketch map showing claims of Vermont Marble Co. on Marble Island.

Southwest from the Tokeen wharf, along the shore of the island, an alternation of limestone beds, intrusive rocks, and marble occurs, but the blue-black limestone crops out around the cove in which the wharf is situated, and near the company's office a small area has been stripped and several blocks of the stone have been taken out. The rock is fine grained and dense but is much fractured and jointed. The openings have been cemented with white calcite. The beds range from 1 foot or less to 3 feet in thickness but on weathering separate into thin layers 1½ to 5 inches thick. (See Pl. X, *A*.) The joints separate the rock in places into small blocks only 1 inch to 3 or 4 inches on an edge. The material takes a fine dark polish. (See Pl. VIII, *B*.) The rock is very brittle and breaks easily, not only along the calcite-filled joint cracks but also along the laminations parallel to the bedding planes. Probably most of the surface material will have to be rejected, but at greater depth the joint cracks appear to become fewer and the rock tougher. The white calcite streaks that intersect the dark surface produce very attractive effects in the polished stone and it was expected that the material would be quarried and marketed as "black marble."

T. N. Dale examined a thin section of this blue-black limestone and found that it consists of calcite, mostly untwinned, measuring with the micrometer 0.009 to 0.094 millimeter, but mostly 0.02 to 0.047 millimeter, and averaging probably about 0.05 millimeter, and is therefore to be classified as of fine grain. The microscope reveals sparse minute opaque specks, probably carbonaceous material, and some cubes of pyrite.

The overburden consists of forest growth and decayed wood and mold 1½ to 3 feet thick. The rocks dip 38°–40° NE., and the edges of their tilted beds have been cut by solution into a very irregular surface. The tramway from the wharf to the marble quarry passes the opening on the blue-black limestone, so that the material can be handled with a minimum of expense.

White and veined marble.—Eastward from Tokeen the blue-black limestone passes beneath the deposit of white marble, which extends to and probably far beyond a small bight on the north side of Marble Island, 400 feet from the quarry. The belt of marble and dark limestone is probably 2,500 feet or more in width, and it extends southeastward into the interior of the island for a much greater distance—possibly entirely across to Orr Inlet. The color of the marble ranges from nearly white with dark-gray and black veins to light-gray and grayish-blue shades. The grain is medium fine and fairly uniform. The marble takes a good polish, and is said to resemble certain grades of Italian marble. Exceptionally grains of iron pyrites are present. The marble having dark veins on a white background is very much in demand at present for interior decoration. Blocks are sawed into slabs, which may be matched so as to form certain nearly symmetrical patterns. Such slabs have been used in a large number of buildings near the Pacific coast. (See "Uses of Alaska marble," pp. 110–112 and Pls. XVI (p. 78), XXIII (p. 92), XXIV (p. 93), and XXV (p. 94).)

Thin sections of the marble from Tokeen were studied microscopically by T. N. Dale. A section of the white marble showed a grain diameter of 0.07 to 1.5 millimeters, mostly 0.52 to 0.2 millimeter, with an estimated average diameter of 0.31 millimeter, falling within the limits of medium grain. The texture is very uneven. One section is crossed by a band of very fine untwinned dolomite (?) along which shearing has taken place. (See Pl. VI, *B*.) A section of the veined white and gray marble, which showed a very uneven texture, includes parts that are extremely fine and parts that are extremely coarse, but in most of the section the grain diameter ranges from 0.025 to 0.625 millimeter, mostly 0.1 to 0.375 millimeter. In the very coarse portions there are grains with a maximum diameter of 0.875 millimeter. The Rosiwal measurements gave an average grain diameter of 0.0051 inch, or 0.13 millimeter. The grade is therefore, in general, medium. The rock shows streaks of very fine, untwinned magnesian calcite grains with graphite. A large grain of pyrite 0.4 millimeter in diameter was noted.

The following determinations made by R. K. Bailey show that the veined marble contains considerable magnesia:

Analyses of white and veined marble from Tokeen.

	White.	Veined.
Insoluble matter	0.01	0.20
Calcium carbonate ($CaCO_3$)	99.51	81.90
Magnesium carbonate ($MgCO_3$)	.94	14.93

The marble appears to be wholly metamorphosed. The material is massive and shows no indication of its original bedding, but it is much jointed and fractured and within 10 to 20 feet of the surface is rather soft. The joint planes cut the deposit at many angles but may perhaps be referred to several systems, the two principal ones striking about N. 50° E. and N. 40° W. The dips of the joint planes are likewise at many angles, and the spacing of the joints is variable, ranging from a few inches to 10 feet or more. In some places parallel joints, or "headings," are rather close together, rendering it impossible to obtain blocks large enough for shipment, but elsewhere blocks 4 by 4 by 10 feet free from cracks may be easily obtained. Wedge-shaped blocks that are completely separated from the surrounding mass by smooth joint planes are occasionally encountered in quarrying. Near the northeast side of the main quarry the marble is cut by a dike of altered andesite porphyry, 8 to 16 inches thick, containing much pyrite and dipping 17°–25° NE. (See Pl. XI, *A*.)

The jointed structure of the marble is the most serious hindrance to its profitable exploitation. It is to be expected that joint cracks should be present at the surface and that surface water should descend along these cracks, enlarging them, softening the marble, and oxidizing it to a faint yellowish hue, but according to experience in many other regions it might be expected that at depths of 40 to 60 feet the joint cracks would disappear and the marble become solid. To the depth quarried in 1912 (60 feet), however, it showed joint cracks in places (Pl. XI, *B*), and it may be possible that the widespread volcanism to which the Pacific coast of northwestern North America has been subjected has disturbed the rocks generally to much greater depths than in other marble-quarrying regions.

The white marble was also analyzed in the chemical laboratory of the Bureau of Standards, with the following results:

Chemical analysis of white marble from Tokeen.

Iron oxide (Fe_2O_3)	Trace.
Alumina (Al_2O_3)	0.14
Lime (CaO)	55.80
Magnesia (MgO)	.47
Sulphur trioxide (SO_3)	Trace.
Loss	43.77
Carbon dioxide (CO_2)	43.86
Insoluble residue	.26
Hydrogen sulphide (H_2S)	Not detected.

Sample has 99.5 per cent $CaCO_3$.

The following physical tests were made for the Geological Survey by the Bureau of Standards on a representative sample of the veined marble from Tokeen. The compression tests show that this marble possesses slightly higher compressive strength than some of the best-known Vermont marbles.[1]

Physical tests of marble from Tokeen, Alaska.

Compressive strength (pounds per square inch).		Absorption (per cent by weight).	Specific gravity.		Condition after 30 freezings.		Modulus of rupture on transverse test.
Dry.	Wet.		Apparent.	True.	Loss in weight (per cent).	Compressive strength (pounds per square inch).[a]	
12,894	12,532	0.104	2.715	2,720	0.02	13,598	1,556
14,547	12,843	.101	2.715	2.734	.02	13,481	1,822
14,452	15,097	.092	2.716	2.729	.02	12,628	1,748
12,255	13,196	....	....	....	....	....	....
Av. 13,537	Av. 13,417	Av. .099	Av. 2.715	Av. 2.728	....	Av. 13,235	Av. 1,709

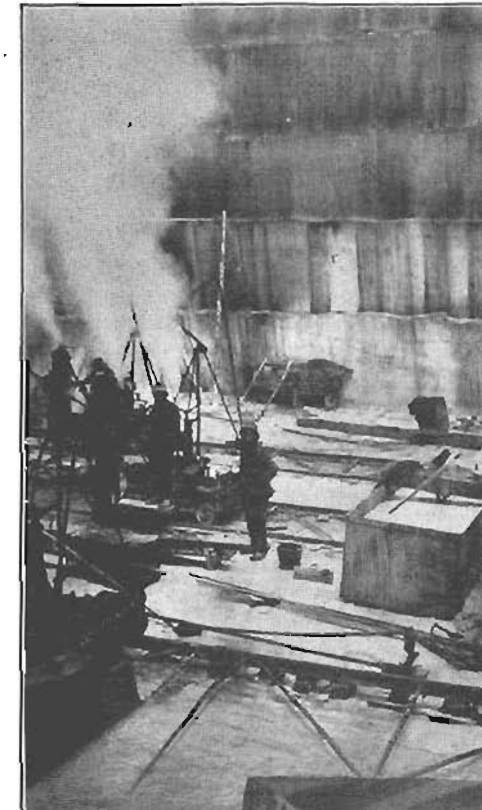
Porosity, 0.48.

[a] Loss in compressive strength, 2.22 per cent.

Quarries.—The main quarry operated by the Vermont Marble Co. on Marble Island in 1912 is about 900 feet northeast of the shore of the small cove at the northwest corner of the island, at an altitude of about 15 feet above the wharf. In places bare knobs of marble are exposed in the vicinity of the quarry, but the surface of the marble, which is very irregular (Pl. X, *B*) as a result of solution and erosion, is generally covered by 1½ to 3 feet of decayed wood and mold. In places the roots of trees have followed the

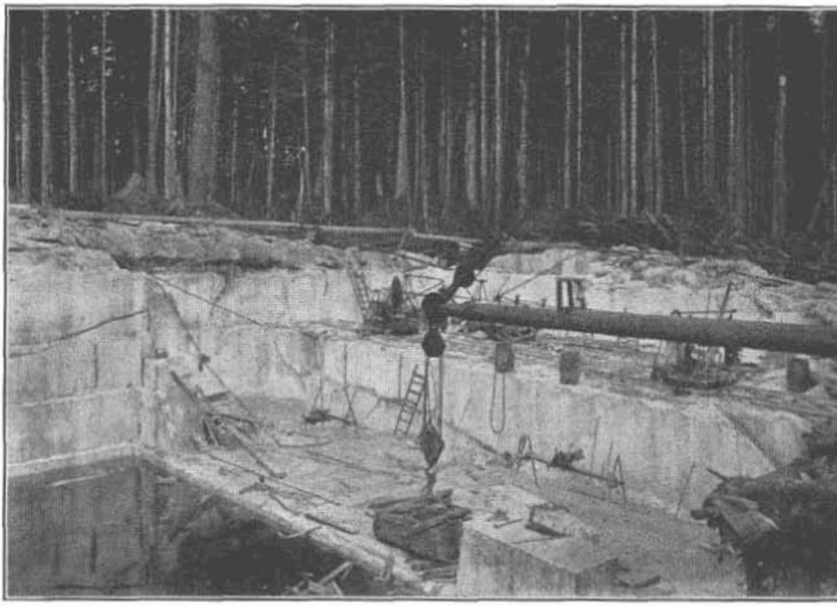
[1] Marble from South Dorset: Average compressive strength per square inch, on bed, 11,300 pounds; on edge, 9,100 pounds. Marble from West Rutland: Compressive strength per square inch, "Extra dark blue," 13,639 pounds; "Rutland Italian," 14,068 pounds; "Rutland statuary," 11,525 pounds. Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, pp. 101, 121, 1912.

A. SOUTHWEST CORNER SHOWING STAIRWAY

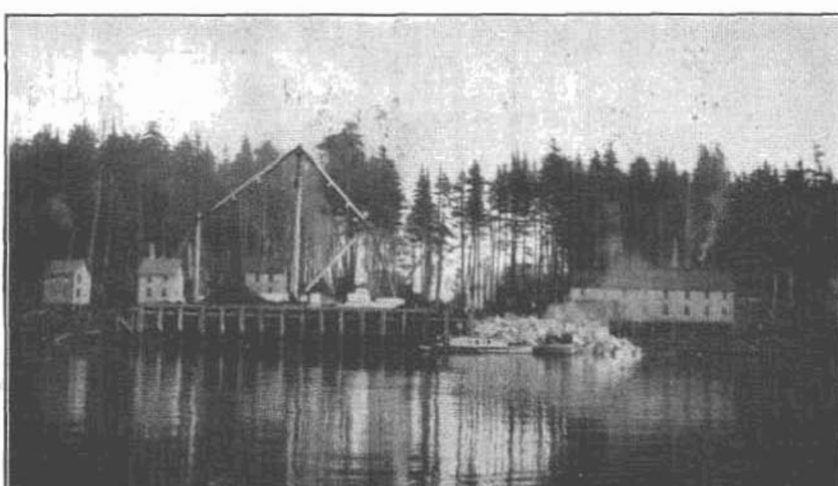


B. LOWEST FLOOR.

VERMONT MARBLE CO.'S QUARRY, TOKEEN.



A. FIRST QUARRY OPENING, VERMONT MARBLE CO., TOKEEN.



B. WHARF AND WATER FRONT OF VERMONT MARBLE CO.'S PROPERTY, TOKEEN.

View shows derrick moving blocks of marble. The pile of rock in the water at the right of the wharf is waste marble.

crevices in the rock to depths of 5 or 6 feet. Trees and stumps are removed by derricks, and the soft mold by hand. The first small opening (Pl. XII, *A*) was abandoned at a depth of about 20 feet on account of several joint cracks 1 to 6 inches or more apart in the northwest end of the cut. These joints dip steeply toward the north, and the quarrying was shifted far enough northwest to avoid them for a time. This dip, however, brings them back into the quarried area at a depth of about 50 feet, and at 60 feet they are apparently about as numerous as at the surface.

In September, 1912, the top of the quarry opening measured roughly 90 by 100 feet, and the depth ranged from 10 to 60 feet. About one-half of the area had been quarried to the maximum depth. Methods of quarrying commonly in use at well-known marble quarries in the Eastern States are employed. (See Pl. XIII.) The equipment in the main quarry consisted of the necessary drills, seven Sullivan single channeling machines, four gadders and pumps, all operated by steam power generated by a 125-horsepower boiler near the quarry, and a complete machine shop. The blocks of marble are lifted from the quarry by a 25-ton derrick and are carried to the wharf (Pl. XII, *B*) on flat cars running on a standard-gage track. The loaded cars move by gravity and are drawn back to the quarry by a $\frac{7}{16}$-inch steel cable. Waste rock is also trammed down to the wharf and dumped into the water alongside the pier. Deep water is reached by a pier about 150 feet long. A 25-ton stiff-leg derrick for unloading cars and loading marble on boats is operated by a small steam boiler on the shore near the wharf.

In September, 1912, a space of $1\frac{1}{2}$ acres about 375 feet southeast of the main quarry was being cleared for a new quarry. (See Pl. X, *B*.) The highest knobs of marble rise here to about 35 feet above the level of the wharf. The marble at this new opening is chiefly white with bluish-gray to black veins and clouds similar to that at the first quarry, but the deposit contains more dark-veined stone. One dike of meta-andesite $1\frac{1}{2}$ to 2 feet thick, striking N. 35° W. and dipping 78° SW., was noted. A full equipment had been installed, and in 1913 and 1914 active quarrying was carried on at this opening, two or three courses of stone having been removed. It is reported that below the surface, as far as quarried, the stone is fairly free from joints and fractures, and a good output of dark-veined marble seems assured.

About 60 men were employed in connection with this plant in 1912. The men live in sanitary and comfortable dormitories, eat excellent fare at a commodious mess hall, enjoy generally favorable conditions under which to work, and show a high degree of efficiency. Quarrying is carried on for eight months or more each year. The winters are not severe, and operations probably can be carried on throughout most of the year when pipes from a reservoir are laid underground so that there shall be no danger of interruptions by freezing of the water supply.

Products.—Rough blocks 4 by 4 by 6 to 10 feet are shipped by freight steamers to the mill of the Vermont Marble Co., at Tacoma, Wash., where they are sawed, polished, turned, or planed for interior decoration. To save freight only perfect blocks are shipped, and therefore considerable material is wasted at the quarry. Some of the waste marble is trammed down to the wharf and used as filling. (See Pl. XII, *B*.) According to the absence or presence of joints the proportion of waste marble quarried may vary between 10 and 75 per cent. The marble for a foot or more on each side of most fractures is discolored and must be cut away. If a fracture crosses the block diagonally or near the middle, it may render the whole block worthless. If cheap power is developed, it might prove an economy to operate a small sawing plant at Tokeen in order to work the waste marble into slabs or building blocks.

Other prospects.—The Vermont Marble Co. has prospected claims about 1 mile and 1½ miles south of Tokeen (No. 34). At one point a white marble of about the same texture as that at Tokeen, but somewhat shattered, is exposed in a small quarry at the base of a low bluff, where, it is reported, marble was obtained many years ago for making tombstones. The surface marble here has been softened by long exposure to atmospheric agencies, and none from any considerable depth was available.

At a second place several variegated marbles have been exposed by prospect pits. The most characteristic varieties are colored light to dark green, bluish, mottled light pink, and brownish gray. The mottled character is due to the presence of veins and nodules of fine-grained, dense calcareous material having a cherty appearance. The green varieties are veined with grayish green, darker than the body of the rock. The rock is massive and jointed and is cut by a thin dike of meta-andesite striking N. 40° W. The deposit was prospected by three or four drill holes, 60 to 94 feet deep, which showed that the green stone changed to gray or bluish within 15 to 25 feet from the surface. A small area was next stripped by hand, and two or three shallow pits were opened by a channeling machine, in the hope of developing a supply of desirable green marble. A wooden track on an incline was built from the test pits a short distance down to the water, in order to get out a few sample blocks of stone, and testing operations have been continued from time to time since 1912.

Between these two prospects there is a beach about 1,600 feet in length, along the greater part of which marble beds are exposed. The marble is veined and is white to grayish. It is cut by several meta-diabase dikes 8 inches to 2½ feet thick, some of which are broken most of the year when pipes from a reservoir are laid underground so that there shall be no danger of interruptions by freezing of the water supply.

Products.—Rough blocks 4 by 4 by 6 to 10 feet are shipped by freight steamers to the mill of the Vermont Marble Co., at Tacoma, Wash., where they are sawed, polished, turned, or planed for interior decoration. To save freight only perfect blocks are shipped, and therefore considerable material is wasted at the quarry. Some of the waste marble is trammed down to the wharf and used as filling. (See Pl. XII, *B*.) According to the absence or presence of joints the proportion of waste marble quarried may vary between 10 and 75 per cent. The marble for a foot or more on each side of most fractures is discolored and must be cut away. If a fracture crosses the block diagonally or near the middle, it may render the whole block worthless. If cheap power is developed, it might prove an economy to operate a small sawing plant at Tokeen in order to work the waste marble into slabs or building blocks.

Other prospects.—The Vermont Marble Co. has prospected claims about 1 mile and 1½ miles south of Tokeen (No. 34). At one point a white marble of about the same texture as that at Tokeen, but somewhat shattered, is exposed in a small quarry at the base of a low bluff, where, it is reported, marble was obtained many years ago for making tombstones. The surface marble here has been softened by long exposure to atmospheric agencies, and none from any considerable depth was available.

At a second place several variegated marbles have been exposed by prospect pits. The most characteristic varieties are colored light to dark green, bluish, mottled light pink, and brownish gray. The mottled character is due to the presence of veins and nodules of fine-grained, dense calcareous material having a cherty appearance. The green varieties are veined with grayish green, darker than the body of the rock. The rock is massive and jointed and is cut by a thin dike of meta-andesite striking N. 40° W. The deposit was prospected by three or four drill holes, 60 to 94 feet deep, which showed that the green stone changed to gray or bluish within 15 to 25 feet from the surface. A small area was next stripped by hand, and two or three shallow pits were opened by a channeling machine, in the hope of developing a supply of desirable green marble. A wooden track on an incline was built from the test pits a short distance down to the water, in order to get out a few sample blocks of stone, and testing operations have been continued from time to time since 1912.

Between these two prospects there is a beach about 1,600 feet in length, along the greater part of which marble beds are exposed. The marble is veined and is white to grayish. It is cut by several meta-diabase dikes 8 inches to 2½ feet thick, some of which are broken and distorted. One dike noted had been faulted and offset horizontally a few feet, but the marble that filled the space between the broken ends of the dike showed only a flowage structure without a definite fault plane. The intrusion of the dike and the deformation of the beds through which it passes probably preceded the metamorphism that produced the marble.

Thin sections of two samples of the variegated marble from the deposit 1½ miles south of Tokeen were examined by Messrs. Dale and Loughlin. The brownish-gray cherty-appearing material is of very irregular texture. The grain diameter of the finer matrix, which consists of untwinned calcite, ranges from 0.025 to 0.075 millimeter, with an estimated average of 0.03 millimeter. The coarser calcitic part shows a grain diameter of 0.05 to 1.125 millimeters, mostly between 0.12 and 0.5, with an estimated average of 0.23 millimeter. Muscovite or phlogopite crystals reaching a length of 0.047 millimeter are widely disseminated. One grain of pyrite 0.7 millimeter in length was noted. A lens of dense dark granular material, cracked and veined with twinned calcite, appears in the section. The texture of the greenish marble was also found to be very irregular. The grain diameter of the finer matrix, most of which is probably untwinned calcite, is 0.02 to 0.12, most of the prominent grains ranging from 0.05 to 0.07, with an estimated average of 0.03 millimeter. The grain diameter of the coarser part, which is calcitic, ranges between 0.12 and 0.87 millimeter, with an estimated average of 0.24 millimeter. Much pyrite and a light-brownish mica (biotite) are present throughout the section, and some dark-grayish, very fine grained bands, cracked and veined with calcite, are prominent. These bands contain much fine epidote, scarce hornblende, and possibly some quartz and other silicate minerals not easily susceptible of recrystallization, indicating that the rock stretched and fractured and the relatively pure carbonate rock recrystallized and "flowed" into the stretch fractures.

The following determinations by R. K. Bailey indicate that there may be some cherty material in the brownish-gray rock:

Analyses of brownish-gray marble from deposit 1½ miles south of Tokeen.

	Brown rock.	Green rock.
Insoluble matter	20.77	7.82
Calcium carbonate ($CaCO_3$)	78.65	91.70
Magnesium carbonate ($MgCO_3$)	1.87	1.21

Limestone, slightly metamorphosed in places but generally a fine-grained bluish rock much fractured and seamed with calcite, alternating with graywacke, forms the coast line around most of the west and south sides of Marble Island. A considerable area of true

MARBLE QUARRY OF MISSION-ALASKA QUARRY CO. JUST BEING OPENED ON ORR ISLAND.

erately coarse grain, with a cream-colored to bluish-white groundmass veined with dark gray, and in places shows mottled effects. Near the surface the veins producing the mottling are oxidized to a brownish color. The appearance of the mottled stone suggests that it may have been derived from a conglomerate, the pebbles of which have been compressed in one direction and stretched in another during metamorphism. Both the veined and the mottled types of stone are handsome in the rough as well as when polished. (See Pl. XV, *A*.) The marble in the north side of the quarry is cut by a dike of andesite, somewhat altered and containing considerable pyrite. For most of its length the thickness of this dike ranges from 2 to 6 feet, but it thins abruptly and terminates in a few irregular branching veins only a fraction of an inch in thickness. This dike strikes about S. 20° E. and dips steeply northeast. A similar and approximately parallel dike was recognized at a prospect about 100 feet northeast of the quarry.

A thin section of the "Dark Mission" veined marble from this locality, examined by T. N. Dale and G. F. Loughlin, showed an abnormal and irregular texture. The stone is made up of coarse and fine grained parts; the very coarse calcite grains have curved twinning planes and an interesting double twinning, and the fine bands have been twinned in a different direction by a secondary movement. A little pyrite is present. The coarse part shows a grain diameter ranging from 0.185 to 4.44 millimeters, but mostly between 1.1 and 2.2 millimeters. The large grains have been strained and curved during shearing or mashing along their boundaries and the fine part shows granulation. (See Pl. XV, *B*.) The estimated average diameter is 0.89 millimeter and the grade is coarse. The grain diameter of the fine part ranged from 0.02 to 0.5 millimeter, mostly 0.125 to 0.25 millimeter, with an estimated average of 0.1 millimeter. A section of a mottled specimen of marble showed an irregular texture, with slightly elongate grains, and a few streaks of fine untwinned grains of calcite. Micrometer measurements of the grain diameter indicated a range from 0.05 to 1.25 millimeters, but mostly of medium grain, between 0.175 to 0.37 millimeter, with an estimated average of 0.25.

Tests by R. K. Bailey showed that both of these marbles are high in calcium carbonate and contain minor amounts of silica and magnesia:

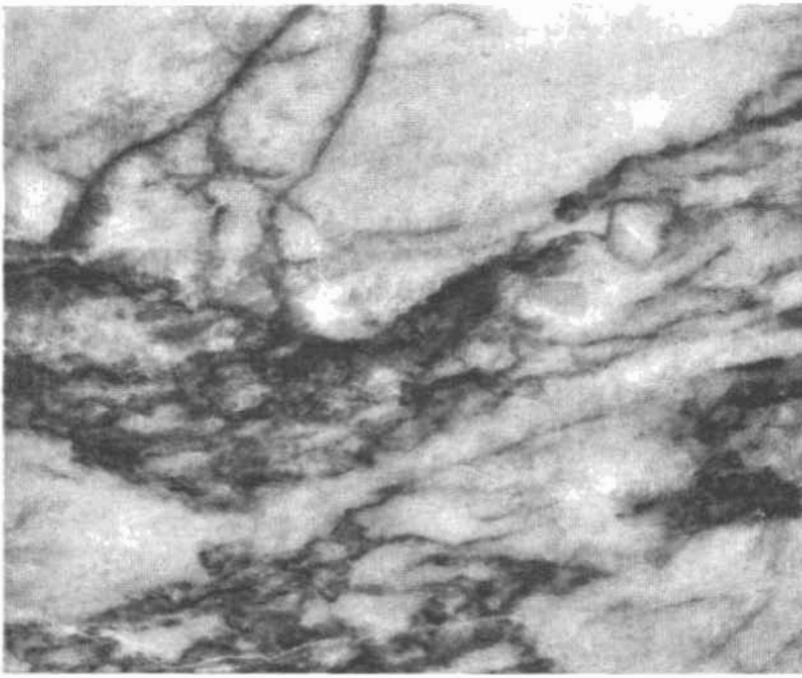
Analyses of marble from Orr Island.

	Dark veined.	Mottled.
Insoluble matter	3.50	2.95
Calcium carbonate ($CaCO_3$)	95.99	95.35
Magnesium carbonate ($MgCO_3$)	1.40	2.04

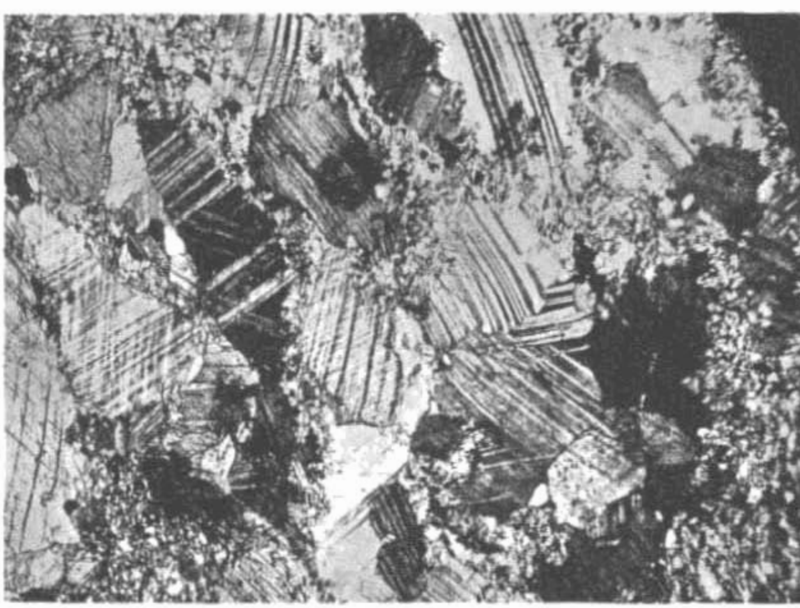
When visited in September, 1912, the quarry had been opened to a depth of about 11 feet only, and for the most part the surface rock had not yet been removed. Two drills and two channelers, both of the Ingersoll type, were in operation, and six or seven 10-ton blocks of marble from the second bench of the quarry were ready for shipment. The first consignment of blocks from this quarry reached San Francisco in February, 1913, and small shipments have been made in succeeding years. The quarry is equipped with hand-power derricks capable of lifting blocks weighing 10 to 15 tons. The marble will have to be carried by scows from the quarry southward about 1 mile and transferred to freighters in deep water. Marble crops out at intervals for several hundred feet along a low bluff parallel to the beach and has been shown to underlie the whole group of claims, but its depth and soundness had not been demonstrated by the drill when the writer visited the locality in 1912. It is reported that openings have since been made about 500 feet farther north and that the rock found was very satisfactory in quality, but that the beds show considerable fracturing. In 1914 progress was reported in testing by means of core drills at an angle of about 45°. In one vertical drill hole good marble more or less fractured was found to a depth of 99 feet.

HECETA AND NEIGHBORING ISLANDS.

In order to verify several reported occurrences of marble on Heceta, Tuxekan, and smaller neighboring islands practically all the remaining shores of Sea Otter Sound and Davidson Inlet, as well as parts of Tuxekan Passage and Tonowek Bay, were examined. The calcareous rocks bordering these shores proved to be for the most part nonmetamorphosed limestone, principally of the gray or blue fine-grained brittle type, with fractures filled with calcite. Near the middle of the north side of Heceta Island (No. 36) is an exceptional limestone colored pink, red, chocolate, green, yellow, and white, with mottled effects. The stone is fine grained, hard, and dense and takes an excellent polish. (See Pl. XVII.) Some of it is conglomeratic. It has been somewhat fractured and recemented with calcite, but it is only slightly metamorphosed, and it yielded a few fossils, among which were recognized *Conchidium* sp., *Capellinia* sp., *Trochonema* sp., *Heliolites* sp., and a pentameroid (?). These forms, according to Edwin Kirk, are of late Silurian age. This limestone crops out at the head of a small bay and was traced southeastward on the strike for about 300 yards and to an altitude of 50 feet or more above high tide. In places the colors are much paler, but the mottled character persists, and much of the stone is attractively colored. An area of graywacke borders this limestone on the west and north. The rock



A



B

A. VEINED MARBLE ("DARK MISSION") FROM MISSION ALASKA QUARRY CO.'S PROPERTY, ORR ISLAND.
B. PHOTOMICROGRAPH OF THIN SECTION OF VEINED "DARK MISSION" MARBLE FROM ORR ISLAND.

Shows the fine and coarse texture of the marble and the curved twinning planes of the coarser crystals. Magnified 10 diameters.

is covered in most places by only a moderate thickness of moss and soil and supports the usual growth of brush and timber. Claims located on this mottled limestone by W. C. Waters are reported to have been sold to the Vermont Marble Co. in 1914. No marble was found on the smaller islands within this area—Cap, Hoot, Owl, Eagle, White Cliff, and Green islands.

An analysis of a sample of this mottled limestone by R. K. Bailey showed considerable insoluble material, probably mostly silica and iron oxide:

Analysis of mottled limestone from Heceta Island.

Insoluble matter	13.18
Calcium carbonate ($CaCO_3$)	84.46
Magnesium carbonate ($MgCO_3$)	2.85

DALL ISLAND.

WATERFALL BAY.

Samples of marble obtained near Waterfall Bay (No. 37), on the west coast of Dall Island, were shown to the writer at Ketchikan by M. D. Ickis in 1912 and found to be of much merit. The principal colors are white, pink, gray, and blue-black. The white and pink varieties are very handsome, the pink occurring in various delicate shades and in areas mottled with white. Some of the white marble is veined with yellow. Green marble is reported to occur but has not been much prospected. The white and pink varieties appear to have been wholly metamorphosed, but the gray and blue varieties appear to possess the characteristics of little-altered limestone. The grain of all the samples is fine, that of the gray and blue varieties exceedingly fine. In the lighter-colored varieties calcite crystals larger than the average are exceptionally present, but in general the texture is uniform, and thin pieces of the stone are as translucent as alabaster. This marble takes a very high polish. (See Pls. XVIII and XIX, *A*.)

These marble deposits, which were not visited by the writer, lie about the head of Waterfall Bay, near the middle of the west coast of Dall Island. Twenty claims in all, aggregating 400 acres, have been located under the names Eurus, Marble Heart, St. Augustine, and Marble Bay groups. Openings are reported to have been made on a steep hillside about 300 feet above tide level and about 1,000 feet from the beach. Assessment work is said to have been done on these claims as late as 1915. A few dikes of "trap" rock 1 foot to 4 feet wide are reported to cut the blue marble beds. The rock is probably much jointed, as many of the samples shown to the writer displayed one or more smooth joint faces. Blocks of the pink marble only 2 to 3 inches wide have been produced by parallel joints. It is said by interested parties that enough marble is available in these claims to warrant development and that several thousand dollars has been expended in prospecting, but emphasis should be given to the often repeated caution that the regional disturbances are likely to have badly shattered this marble.

Theodore Chapin, of the United States Geological Survey, visited the Waterfall Bay region in the summer of 1915, and as a result of his observations contributes the following notes on the geologic relations of these marble beds:

The geology of the region is simple. South of the bay the rock is limestone. The dominant color is blue to black, with lighter-colored areas where marmarized. Overlying the limestone with apparent conformity is schistose greenstone containing conglomerate beds, occupying the north shore of the bay. The contact extends about N. 75° E. from the cabin at the head of the bay. Both limestone and green beds stand nearly vertical but dip northwest at high angles except where overturned. The best marble noted occupies a belt of varying width along the greenstone contact. At one locality marble crops out to a measurable width of 400 feet, besides a considerable thickness of semicrystalline limestone. The marble has been exposed by surface stripping for several hundred feet from the head of the bay. At 300 feet from the cabin, at an altitude of 220 feet, the following section is exposed:

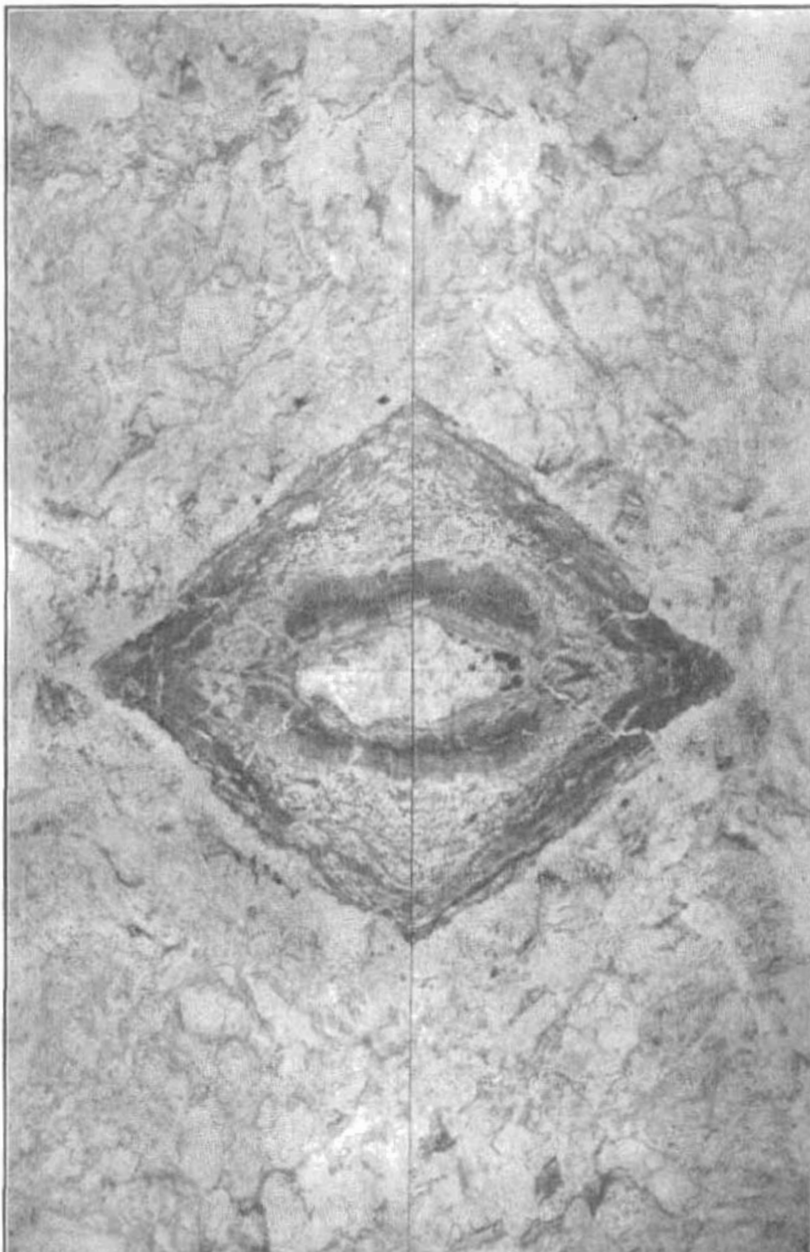
Section of marble on Waterfall Bay 300 feet from cabin.

	Feet.
Greenstone.	
Bluish-gray marble crops out only at intervals	300
Blue and white mottled marble	4
Dike	½
Thin-bedded white marble with black specks and white mica	4
Pink-mottled white marble	13
Blue and white mottled marble, exposed	25±
Base concealed.	

The best commercial marble in this section is the 13-foot bed of pink-mottled white marble. The upper and lower parts of the bed are even-textured, medium to fine grained white marble mottled with a very delicate pink tint and veined with irregular threadlike veinlets of yellow. In the central part of the bed the pink color is more pronounced and the rock contains much white mica, a combination that produces a handsome rock. A short distance beyond this locality the following section is exposed:

Section of marble on Waterfall Bay 600 feet from cabin, at an altitude of 400 feet.

	Feet.
Schistose greenstone.	
Bluish-gray marble (in part mottled and veined with black)	300
Fine-grained white marble with brown veinlets carrying mica and pyrite	26
White marble with green patches and brown veinlets	7
Fine-grained white marble with brown and green veinlets carrying mica and pyrite, contains a few large crystals of calcite	9
White and pink marble with green areas	11



PANEL OF BRECCIATED MARBLE FROM TOKEEN, FORMED BY MATCHING SLABS SAWED FROM SAME BLOCK.

	Feet.
Fine-grained white marble with pyrite in tiny veinlets and disseminated in particles	16
Quartz schist containing pyrite	1
White marble, with pyrite and much chlorite in tiny stringers and veinlets	10
Dike	2
Concealed	15
Blue limestone, with beds of white marble and schistose beds, grading downward into fossiliferous limestone.	

The white and pink marble with mottled-green areas is very handsome and susceptible of a high polish, except where the green minerals predominate. The greater part of the bed is white and pink marble, composed of nearly pure calcite of very fine grain, the individual minerals averaging about 0.05 millimeter in diameter. The base and top of the bed are variegated with green areas, which, combined with the pink-mottled white rock, give a very striking effect. Under the microscope the green areas are seen to consist of sericite, quartz, and chlorite; the white and pink rock is essentially calcite. The great thickness of bluish-gray marble at the top of the measured sections contains beds of ornamental marble of commercial value. These beds are black and white, mottled in very intricate pattern, and bluish white with black veinlets. This rock takes a smooth polish.

Marble crops out at several places along the south shore of the bay between the cabin and the greenstone contact. Near the cabin an opening has been made on a bed of fine-grained, even-textured white marble, carrying flakes of white mica. Another commercial marble on this bay is a fine-grained black variety that takes a good polish. The polished surface shows a black field with white-mottled areas and irregular veinlets of white calcite, which give it a pleasing appearance.

Two specimens of the marble from Dall Island were examined by T. N. Dale and G. F. Loughlin. A section of the white variety was found to consist of plates of fine-grained twinned calcite in a matrix of extra-fine, untwinned grains of calcite. The general texture of this marble resembles that of a marble from the Huntley quarry at Leicester Junction, Vt., which has an uneven parallel elongate texture with alternate irregular tiers of large and small grains,[1] called "flaser" structure, but the marble from Dall Island is less regular. The twinned calcite plates range in diameter from 0.075 to 0.375 millimeter but mostly from 0.125 to 0.25 millimeter, and would be considered of medium grain. The grain diameter of the matrix material is fine, measuring from 0.009 to 0.037 millimeter. (See Pl. XVIII, *B*.)

The other specimen consisted of fine-grained, considerably fractured stone, having a gray groundmass containing a few irregular reddish mottlings and several white and yellow streaks along fracture planes, also some granular calcite filling former openings along fracture planes. The section showed an extra fine grained ground-

[1] Dale, T. N., The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, pp. 147–148, fig. 25, 1912.

mass crossed by a band 0.66 millimeter wide, faulted transversely, consisting of calcite plates 0.094 to 0.56 millimeter in diameter. The groundmass shows a grain diameter ranging from 0.02 to 0.14 millimeter, but mostly from 0.037 to 0.076 millimeter. The estimated average diameter is 0.04 millimeter, and the grade is fine.

An analysis of the white marble by R. K. Bailey gave the following percentages:

Analysis of white marble from deposit near Waterfall Bay, Dall Island.

Insoluble matter	0.32
Calcium carbonate ($CaCO_3$)	99.59
Magnesium carbonate ($MgCO_3$)	1.03

BREEZY BAY.

In the autumn of 1914 and early in 1915 W. C. Waters examined the east shore of Dall Island and portions of Long Island and sent to the Survey samples of limestone and marble collected from several localities in these areas.

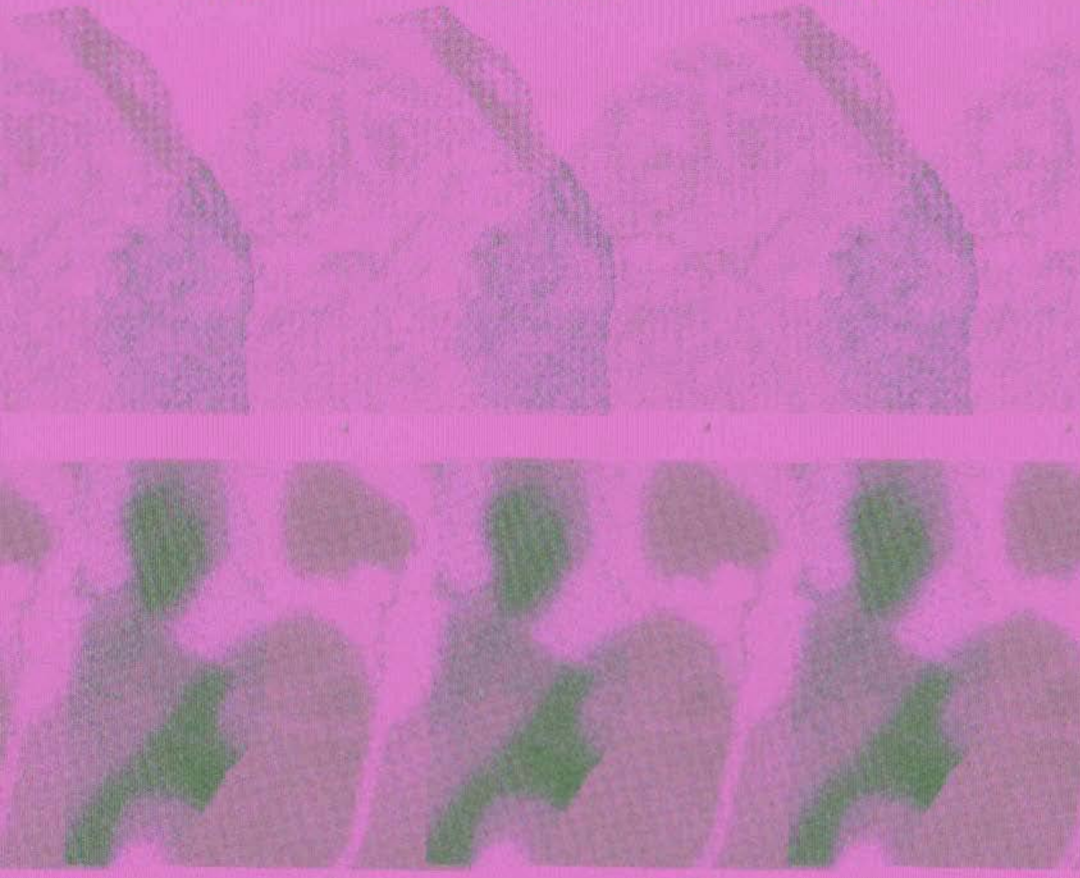
Mr. Waters's notes show two narrow areas of marble striking in a westerly direction from the northern part of Breezy Bay (No. 38) and an area of limestone a short distance to the south of the marble. The color of the sample of marble from Breezy Bay is uniformly light gray, and the texture is generally fine grained and dense as seen under a field lens. The rock is evidently composed mainly of calcium carbonate. The ledge is reported to be about 100 feet wide and to stand nearly vertical, with a west-southwest strike. So far as explored there was little cover besides moss over the ledge.

VIEW COVE.

Mr. Chapin also visited certain portions of the east coast of Dall Island. With regard to a deposit near View Cove (No. 39) he furnishes the following notes:

> Marble deposits occur on the east coast of Dall Island at a number of places. Near the head of View Cove a stream that enters from the southwest flows in a gorge following joint planes in the marble. This stream was traversed from the beach for half a mile and in that distance the beds strike about northwest, directly across the course of the stream, and stand nearly vertical. Most of the marble seen is pearl to gray in color and mottled and veined with white. At one locality occurs a 4-foot band of yellow marble with a green stripe, and bordering it is white marble mottled with yellow. The yellow marble takes a good polish and has a warm, soft tone. Associated with these beds is a little bluish-black marble. A polished specimen shows a black field variegated with dark-gray areas and tiny veinlets of white calcite.

Mr. Waters also reports that several colored varieties of marble occur here, including white, pearl, light with black veining, black, green, and yellow, and has sent samples of the pearl-colored, gray-



veined, yellow, green, and black varieties to the Survey. The pearl-colored rock, in the hand sample, gives brisk effervescence with hydrochloric acid and is uniformly fine grained and dense, except for a few thin streaks of crystalline calcite. The color is not uniform but shows gradations from pearl to gray. A few small specks of pyrite were noted along a fracture plane. A thin section of this marble was examined by G. F. Loughlin, who reports that the material shown is nearly all even-grained calcite with a few large grains (single or aggregates) as much as 2 millimeters in diameter. The fine grains range from 0.01 to 0.3 millimeter in diameter and average about 0.08 millimeter. The grade of texture is therefore fine. A very few minute black grains, some certainly of pyrite, were noted; the largest was 0.035 millimeter in diameter. A few flakes of graphite may be included. The section also shows a very few grains of quartz 0.03 or 0.04 millimeter in diameter.

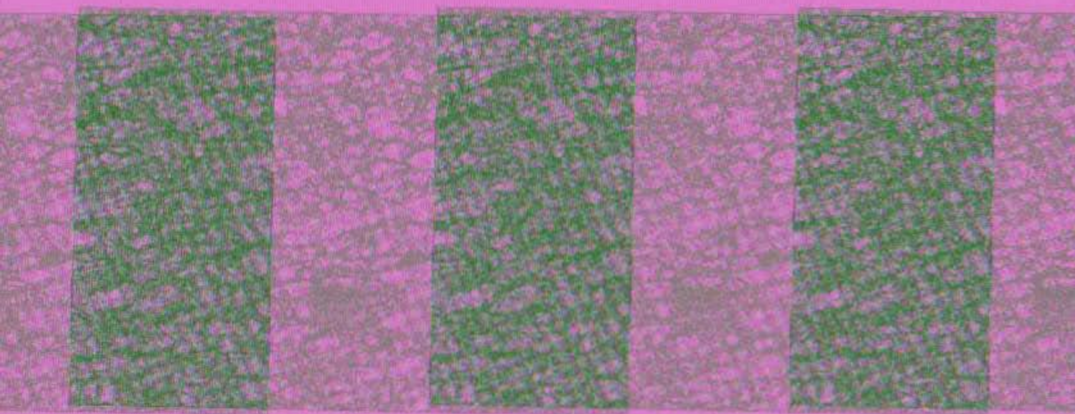
The gray-veined material consists of medium-grained calcite with veins and spots of darker-gray finer-grained material showing close-folded structure. If large slabs of this marble could be obtained the effect, after polishing, would be very handsome.

The black marble is bluish-black in the unpolished sample. It is a fine-grained, dense high-calcium limestone, possessing the color and density characteristic of rocks that are susceptible of high polish and that show a deep black color on polished surfaces. The rock is brittle and shows fine fractures recemented with calcite, and for this reason it is probably questionable whether large thin slabs could be prepared from it.

The yellow sample (see Pl. XIX, *B*) is generally fine-grained, dense high-calcium marble. It takes a high polish, which brings out well the color, a warm light brownish yellow that resembles the yellow areas in the Italian Siena marble. This color in the hand sample, which is 3½ by 4 inches, is not uniform but becomes slightly lighter toward one edge. This is a very handsome marble, and if it can be obtained in large quantities and the conditions for quarrying and transportation are favorable, the deposit should prove to be very valuable.

The green marble is also fine grained, and consists mostly of calcite but carries dark streaks of micaceous carbonaceous material with considerable pyrite. The general effect in the hand sample is grayish with clouded areas of grayish green, streaks of black, and here and there mottlings of light gray, giving altogether a very attractive appearance. The rock takes a high polish except along the black streaks, which consist of material harder that calcite.

The marble in the vicinity of View Cove is all of the calcite variety.



coarse grained and to contain mica, but no mention is made of its color, and although a sample was sent it did not reach Washington.

Limestone and marble are also reported in the vicinity of Kaigani Harbor, but no descriptive details are available.

CAPE MUZON.

A bed of schistose marble 10 to 100 feet wide and 2 miles long "in the vicinity of Cape Muzon" is reported by Mr. Waters, who notes that the bed strikes west and stands nearly vertical. The material is reported to be white, pink, and green. A sample received by the Survey is of brownish-pink color, medium grain, and bright appearance. From notes on a chart sent by Mr. Waters it appears probable that this marble crops out west of McLeod Bay (No. 44).

LONG ISLAND.

The northern part of Long Island appears to contain promising areas of marble. This part of the island is largely surfaced by calcareous rock. Theodore Chapin, who visited this locality in the summer of 1915, reports as follows:

> Deposits of marble have recently been located near the northwest end of Long Island, 3 to 4 miles north of Howkan, on two small bays known locally as Waters and Gotsongni bays. At this locality the brush is very thick along the shore and outcrops are few, making prospecting difficult, but physical conditions favor the exploitation of the deposits. The shore of the island rises abruptly from the beach, the timber is plentiful and of an exceptionally good grade, and the deposits occur on sheltered harbors which afford easy access to boats.
>
> On Waters Bay three claims, the Lily, Long Island, and White Cloud, have been located, and assessment work has been done. Most of the marble exposed has a bluish-white field with white-mottled areas and blue-black stripes. Under the microscope the rock is seen to be composed essentially of twinned calcite crystals ranging in size from 0.25 to 0.7 millimeter, inclosed in a network of finely granular calcite that averages about 0.05 millimeter and forms with the large calcite crystals an intersertal fabric. The large calcite crystals are bent and fractured. They are evidently crushed fragments around which the fine-grained calcite has recrystallized. The black stripes are composed of opaque particles of carbonaceous material, probably graphite. Associated with the striped marble are beds of medium-grained white marble of even texture and also beds of blue-clouded white marble with yellow patches. This rock takes an excellent polish.

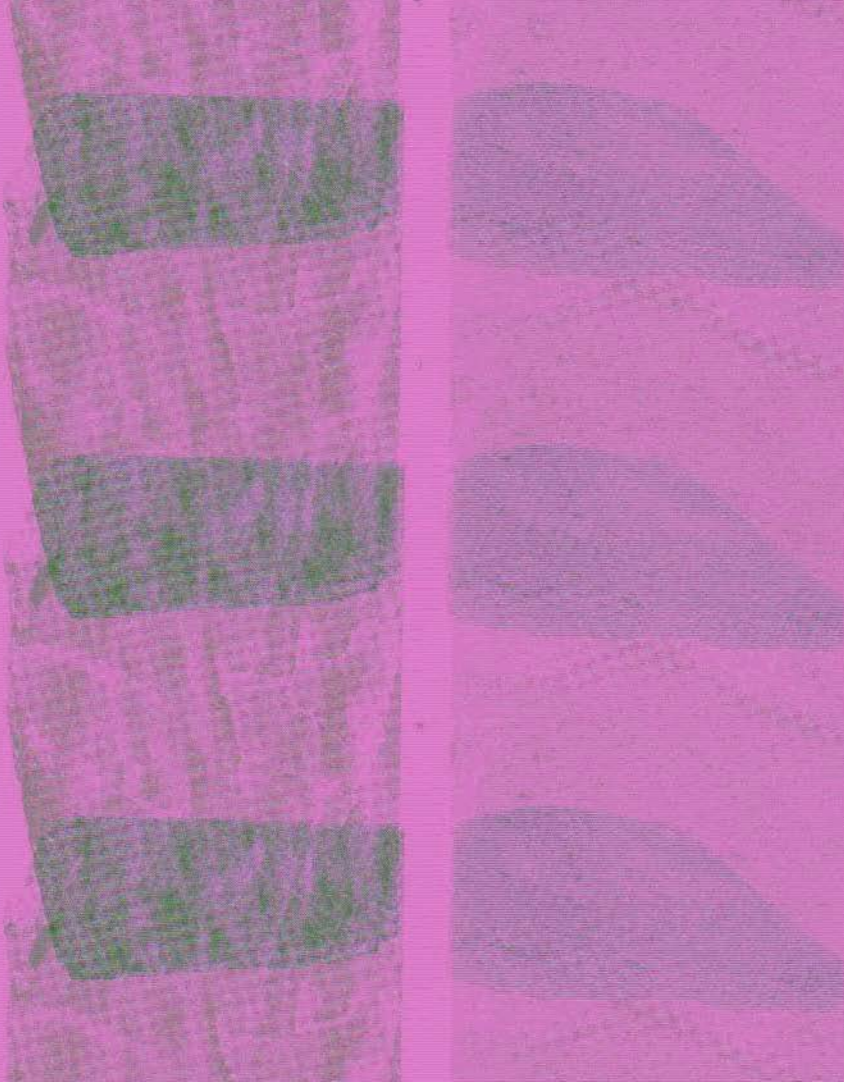
The deposit at the head of Waters Bay (No. 45) is reported by Mr. Waters to strike northwest and to extend up both sides of a small stream for a distance of a mile, with a width of 2,000 feet. Samples of white, pearl-gray, gray-banded, and gray-veined marble from this locality were received at the office of the Geological Survey. The white marble is medium grained and shows faint pinkish-yellow tints. The hand sample is of granular texture, shows a bright, sparkling surface, and is translucent on thin edges. When struck it gives a clear ring.

A thin section of the pearl-gray marble was examined by G. F. Loughlin. The material as seen under the microscope appears to be rather even-grained calcite, mostly twinned, with fine granulated borders. The grain diameters range from 0.08 to 0.7 millimeter and average between 0.20 and 0.25 millimeter, as the coarser grains predominate. The grade is, in general, medium. A few very fine oxidized pyrite grains scattered through the section were noted. The largest of these is only 0.04 or 0.05 millimeter in diameter. The section shows several minute limonite pseudomorphs after pyrite, also a few streaks of limonite, sufficient to give a pale-brown streak across a hand sample of the marble. A shear zone, containing rounded grains and a few very fine grains of quartz in a matrix of pulverized calcite, was noted. No quartz was seen elsewhere in the section. So far as the material in the thin section is concerned, oxidation is practically completed and no further staining from pyrite is likely. In fact, pyrite is so rare in the sample as to cause a negligible amount of staining.

The banded marble is similar in texture to the white marble but has a light-gray body with parallel straight thin bands of darker gray spaced one-eighth to one-half inch apart. The veined marble is similarly colored but less uniformly grained. The veins and clouded areas show attractive patterns produced by folding of the rock. It is reported that this deposit appears to be "solid"—that is, comparatively free from fractures and joints.

According to Messrs. Chapin and Waters there is at the northwest corner of Long Island, on the east side of Gotsongni Bay about three-quarters of a mile from the head of the bay (No. 46), an exposure of marble half a mile in length. The beds appear to strike north-northwest, or parallel with the axis of the bay. On the beach are outcrops of coarse-grained even-textured white marble. A short distance back from the beach and separated from the white marble by a brush-concealed strip is a large area of bluish-white to bluish-gray marble with black stripes. The rock is medium grained and even textured. It takes a good polish and is apparently free from quartz. White and pink varieties of marble are also reported to occur in this locality.

A sample of the white marble sent to Washington by Mr. Waters is medium-grained calcitic material with a bright, sparkling surface where freshly broken. The rock possesses a high degree of translucence. A thin section of this marble was examined under the microscope by G. F. Loughlin. The material is composed of large



irregular grains separated by a network of fine grains. This texture is due to granulation along the boundaries of the crystals and has been termed "flaser" structure. (See p. 79.) The diameter of the interstitial grains is 0.02 to 0.10 millimeter with an average of about 0.04 millimeter. The coarser grains are 0.02 to 2.6 millimeters across and average about 0.06 millimeter. The average grain diameter of the marble, according to Mr. Chapin, is 0.25 millimeter. The only impurities noted by Mr. Loughlin were a cluster of pyrite (?) grains about 0.14 millimeter across and one very minute crystal of quartz (?).

A sample of the pink marble consists of medium to coarse grained crystalline calcite, of a salmon-pink shade. The rock takes a good polish, and the polished surface brings out slight variations in the pink color and also several streaks of colorless calcite.

An area of marble at Howkan is shown on Mr. Waters's field map, but no notes concerning it are available.

SOUTHEASTERN PART OF PRINCE OF WALES ISLAND.

DOLOMI.

Certain marble deposits on the east side of Prince of Wales Island in the vicinity of Dolomi were described by the Wrights,[1] and as no new work was reported to have been done on the claims, they were not visited by the writer. The notes originally published are given below.

The properties of the American Coral Marble Co. are located at two localities—at the head of North Arm [47], where 12 claims have been located along the north shore of the inlet, and at the north entrance to Johnson Inlet [48], where the company has several claims extending from Dolomi eastward to Clarence Strait. The principal developments have been made at the North Arm property, and at this point a post office named Baldwin has been established. Active work at this locality began in 1904, and the marble deposits were prospected during that year. In 1905 a wharf was built, machinery installed, and buildings erected preparatory to quarrying the marble. During 1906, however, practically no work was done, and all of the machinery was removed in 1907. At the Dolomi property a small quarry was started on the hillside, at a point a quarter of a mile northeast of Dolomi post office and a few hundred feet from tidewater on the Clarence Strait side, and buildings were erected. No operations were in progress at these localities during 1907 [and none has been reported up to 1916].

The deposits at North Arm and at Dolomi consist of marble beds interstratified with chloritic and calcareous schists, striking northwest with steep dips, usually southwest. The surrounding area is mantled by a dense growth of vegetation, and the limits of the deposits have not been definitely determined, though where the marble is exposed it is much fractured, variable in color and composition, and intersected by a few narrow dikes of diabase. The fracture planes were probably formed principally during the period of tilting and folding of the beds and existed before erosion exposed the present surface outcrops.

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[1] Wright, F. E. and C. W., op. cit., pp. 196–197.

Since that time weathering has accentuated and to some extent increased the number of fracture planes, and it seems probable, however, that in depth these planes, although potentially present as lines of weakness, will become less numerous and will not interfere greatly in quarrying.

Although some parts of the deposits consist of pure-white fine-grained marble of excellent quality, other parts are poorly colored, coarse grained, and of little commercial value, and it will probably be difficult to obtain large quantities of uniform grade. The better grade is reported to give the following analysis: Calcium carbonate, 94 per cent; alumina, 3.9 per cent; silica, 1.4 per cent; magnesia, 0.7 per cent. Pyrite is also present in small amounts, occurring in thin seams and finely disseminated in some of the marble.

DICKMAN BAY.

Location.—An area of particular interest on account of the large variety of marble which it affords lies in the southeastern part of Prince of Wales Island, in the peninsula between Dickman Bay (so named on Coast and Geodetic Survey chart 8100) and the unnamed narrow inlet to the north, here designated Shamrock Inlet (No. 49). Dickman Bay is an extension of West Arm of Moira Sound, and the area lies 11 to 12 miles southwest of Dolomi. According to a booklet published in 1913 by the owners, the Alaska Shamrock Marble Co., of Portland, Oreg., two groups of claims have been located—group 1, consisting of eight claims (United States Mineral Survey No. 946), and group 2, consisting of four claims (United States Mineral Survey No. 947), together aggregating 228 acres.

Relations and character of the marble.—The marble occurs in beds of varying thickness which strike N. 30°-40° W. and dip steeply southwest. It is interstratified with graywacke and schistose beds and intersected by dikes of diabase and basaltic rock. A small area of dark-gray granitic rock is exposed at the southeast point of the peninsula and appears to be in contact with the marble mass. The marble is more or less schistose in places, especially near the contacts of schistose beds, and it is banded locally near the contacts of dikes by the interlamination of marble and dike rock in layers ranging from less than 1 inch to several inches in thickness. Ledges of marble 20 to 75 feet wide alternate with areas of graywacke 50 to 1,000 feet across and have been traced in the direction of the strike for a mile or more. The surface exposures show more or less jointing and fracturing of the beds.

The surface of the peninsula north of Dickman Bay is rough and wooded. The banks generally rise abruptly from deep water, and the highest marble ledges reach an altitude of 350 to 500 feet above sea level at a few hundred feet from the shore.

Most of the marble on the Alaska-Shamrock claims is of fine grain, although in a few places some very coarsely crystalline material was noted. Numerous samples sent from the prospects to Portland,

SAMPLES OF COLORED MARBLE FROM DICKMAN BAY IN OFFICE OF ALASKA-SHAMROCK MARBLE CO., PORTLAND, OREG.

Some of these slabs afford striking illustrations of mashing and brecciation.

Oreg., have been polished and have revealed a large variety of colors in a great many combinations. As a rule the rocks take a good polish. The veins which produce the beautiful effects in the strongly veined or schistose marble do not take so uniform a polish as the calcite portions of the stone. The inequalities in the polish are due to the presence in the veins of minerals of varying degrees of hardness, such as quartz, mica, and chloritic materials, and are not noticeable unless the light falls on the surface at an angle.

Certain of the varieties of marble obtained here are white with golden-yellow veining, grays of various shades, gray veined and mottled with white, pink, and yellow; pale green, grass-green, green with black and white, green with pink and white, black and white, plain black, and of other color combinations. (See Pls. XX to XXII.) In thin sections the green color appears to be due to chloritic material and possibly to some epidote. Among the trade names adopted by the company to designate some of the more striking varieties of the marble are "white and gold," "Confederate gray," "moss-agate green," "raven-black," and "jewel marble." The last is a veined or mottled stone generally showing strong contrasts between dark green, white, and pink and having a few pink calcite crystals either isolated or in bunches. The color of these calcite crystals, which suggests that of garnet, is due to the presence of disseminated fine grains of hematite.

Thin sections of five samples of marble from the Alaska-Shamrock claims were examined microscopically by T. N. Dale and G. F. Loughlin.

A section of the grayish-white marble showed an uneven texture with streaks still firmer than the very fine grained groundmass. These streaks contained also sparse quartz and muscovite. Micrometer measurements of the general groundmass gave a grain diameter ranging from 0.025 to 0.5 millimeter, mostly between 0.05 and 0.25 millimeter, with an estimated average of 0.1 millimeter.

A section of the banded white and blue marble is composed of light bands of regular texture alternating with bands of finer grains with much graphite, a few large calcite grains, and a little muscovite. The grain diameter of the white bands ranges between 0.05 and 0.5 millimeter, mostly 0.125 to 0.25 millimeter, with an estimated average of 0.125 millimeter.

A section of the banded green and white marble showed a groundmass of white bands containing many grains of plagioclase (?) and some of quartz measuring as much as 0.25 millimeter, with irregular bands of fine-grained epidote, chloritic material, calcite, and a little quartz. The groundmass has grain diameters of 0.025 to 0.32 millimeter, mostly 0.075 to 0.2 millimeter, with an estimated average of

0.075 millimeter. The calcite grains in the green bands have a grain diameter of about 0.06.

A section of grass-green marble consists of calcite plates, mostly untwinned, quartz grains, with rarely one of plagioclase, finely disseminated minute scales of chlorite, a few of biotite, and plates and quartz grains and some pyrite. The calcite plates measured by micrometer range between 0.02 and 0.094 millimeter, but mostly between 0.03 and 0.056 millimeter.

The section of the "jewel" marble was not measured for grain diameter. The groundmass is mainly calcite, but chloritic material and quartz occur, especially in the green areas. The red or "jewel" areas consist of calcite colored by hematite grains. These red areas are crossed by colorless veinlike streaks which may be aragonite or possibly strained calcite.

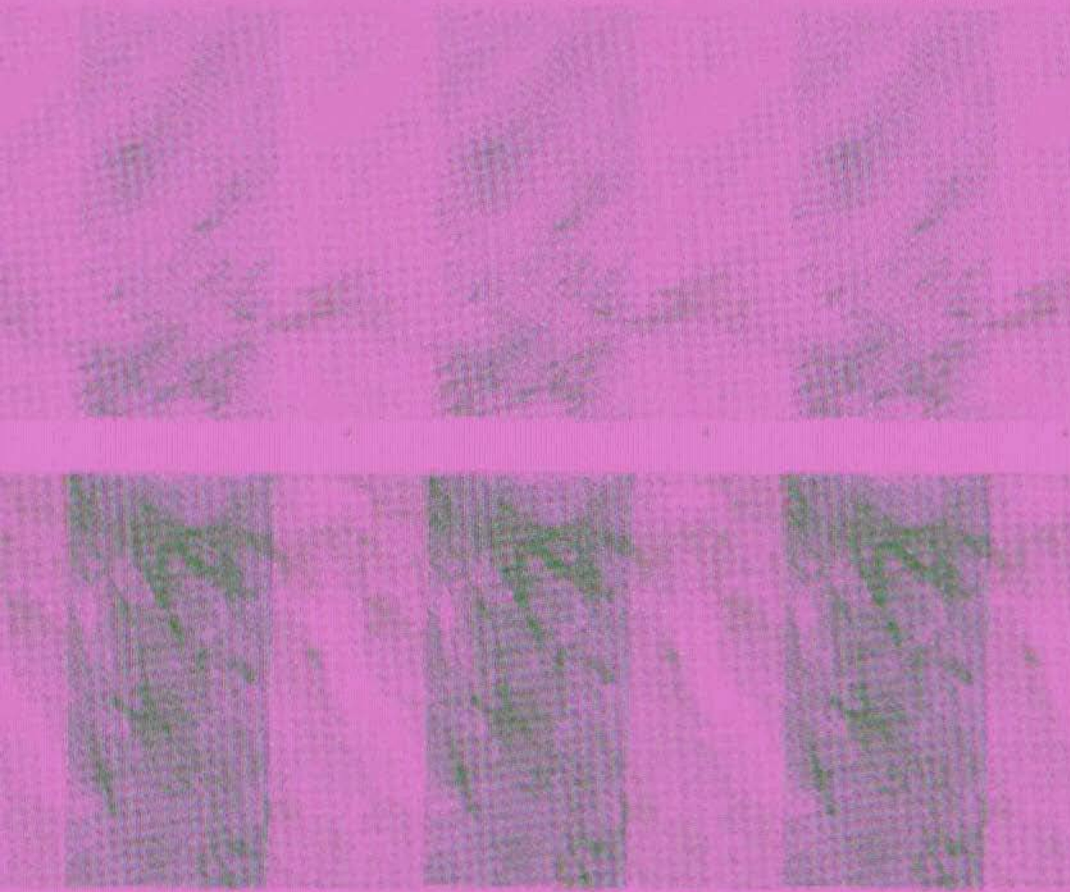
Two samples analyzed by R. K. Bailey show high percentages of insoluble material and a moderate percentage of magnesia.

Analyses of marble from Dickman Bay.

	"Jewel" marble.	Dark-green marble.
Insoluble matter	22.84	37.32
Calcium carbonate ($CaCO_3$)	74.61	58.40
Magnesium carbonate ($MgCO_3$)	3.25	6.61

Prospects.—Three or four openings have been made on marble beds that crop out on the shore of Shamrock Inlet. At the prospect nearest the southeast point of the peninsula work was in progress in Ocober, 1912. A small clearing had been made, several houses and a machine shop had been built, and blocks were being detached from a ledge of marble banded with dark-gray and white veins. The marble is brittle and somewhat schistose and splits readily along the laminations. On weathered surfaces the harder portions of the rock stand in relief above the more calcareous portions. A hand derrick was used here in clearing away stumps and raising blocks of marble.

Northeastward along the shore of the inlet other openings disclose alternations of light-colored and blue marble. One opening is in beds of very fine grained cream-colored marble slightly veined with yellow. At this place the beds are exposed for about 100 feet horizontally and 30 to 40 feet vertically. The strike is N. 75° W., and the beds stand nearly vertical. The surface of the beds is rough and fractured, with deep crevices produced by solution, and the mass is cut by a basaltic dike that has been faulted and twisted since its intrusion into the marble. Where badly fractured the beds will have to be quarried deeply in order to ascertain the possibility of obtaining blocks of adequate size.



Two of the most interesting prospects are on a ridge extending northwest from the camp, in the direction of the strike of the rocks. The marble ledge that has been opened is 70 to 75 feet wide between two dikes that have weathered more slowly than the calcareous mass and that form walls on either side of it. At the upper opening, about 800 feet from the shore and 350 to 400 feet above tidewater, the marble is principally green. The beds are exposed for about 150 feet along the strike. The green color appears to become paler toward the northwest, although small patches of stone among the paler areas are of fully as deep a green color as any others in the deposit. The deeper shades of green seem also to occur nearest the top or surface edges of the beds. Prospecting with a core drill is recommended if more definite knowledge is desired regarding the continuation of green shades in depth. The rock here is not so badly fractured at the surface as along the shore, and it is possible to get out some very good sized blocks without quarrying deeply. A 1-ton block, which was moved on skids down the trail to the beach, has already been shipped to Portland, Oreg. Another opening on this same ledge was noted about 600 feet from the beach and about 200 feet above water. The beds here are banded with dark blue or gray and white near the southwest wall, but the blue bands change to dark green near the middle of the ledge. A small mass of garnet-colored calcite was noted in the rock at this place.

At these prospects it has been necessary to clear away a vigorous growth of timber and to strip off a cover ranging from a few inches of moss on the exposed places to soil 6 or 7 feet thick in the crevices and hollows in the rock.

Other prospects of the Alaska-Shamrock Marble Co. are situated on this peninsula on the north shore of Dickman Bay and extend up a small bight about three-quarters of a mile from the extremity of the peninsula. The dip and strike and the position of the beds exposed here indicate that they are probably continuations of the ledges near Shamrock Inlet. Diabase dikes have intruded the beds in this locality, and the surface exposures of the stone show much jointing and fracturing. The marble occurs in various shades of white, bluish gray, and green. In polished samples some of the green marble compares favorably with the "verde antique" types produced in the United States. The beds crop out in bold cliffs on both sides of the small cove, and they also form its floor and extend inland beyond the head of the cove. This area was the first one to be prospected by the Alaska-Shamrock Marble Co. The prospecting has been done mainly by hand drilling and loosening blocks with black powder. Considerable material has been shipped to Portland for exhibition. Another possible resource of this company is the gray granite that crops out on the shore of Dickman Bay between the two marble localities.

A letter from the company dated September 9, 1914, indicates that prospecting had been continued with encouraging results consisting of additional discoveries of large quantities of attractive marble, including the "jewel" stone, pink and gray, "Irish green," white and gold, verde antique, dark stone with a grain resembling that of fir when cut in the direction of the grain, and stone having intermingled green, black, gray, white, and pink colors. Eight blocks having an average weight of 7 tons each and two blocks of 12 tons each are reported to have been shipped from this locality to Portland, Oreg.

Some decorative work in Portland is reported to have been done with this marble, such as the entrance to the Charlotta Court at Seventeenth and Everett streets, in which was used a reddish-brown and white-banded combination with a background of Colorado Yule marble, and the entrance to the Majestic Theater at Park and Washington streets (see Pl. XXVI), which was paneled with black and white brecciated marble having a garnet-colored stain in some of the black areas.

The reported discovery of a large quantity of verde antique marble seems to be especially important, as there is a considerable demand for marble of this type for trimmings in interior decorative work, and it is beginning to be used for exterior work, such as borders for doorways or show windows.

Much of the marble available in this locality is of great beauty when finished, but the geologic structure of the beds suggests that there will probably be considerable waste in quarrying and in finishing. Much more prospecting and development work must be done in order to ascertain whether or not the properties can be exploited on a commercial basis. All the properties are situated most favorably for shipping quarry products. Deep water extends practically to the shore line, except in the small cove, and both Dickman Bay and Shamrock Inlet afford roomy and sheltered harbors.

MAINLAND EAST OF WRANGELL ISLAND.

A long, narrow belt of crystalline limestone, containing true marble in many places, extends in a northwesterly direction on the mainland for a distance of about 17 miles, beginning at Blake Channel and lying nearly parallel to Eastern Passage.[1] Blake Channel itself follows the strike of this belt and may represent a drowned valley developed along these comparatively soluble rocks. At the south

[1] U. S. Geol. Survey Bull. 347, pl. 3, 1908.

end of Blake Channel certain small areas of marble, including Ham Island and areas on the north and south sides of Bradfield Canal, are also practically in strike with this belt. The metamorphism of this limestone to marble has probably been caused by the intrusion of wider belts of granite to the east on the mainland and to the west on Wrangell Island. Metamorphic minerals such as talc are present in the marble deposit near the east end of Lake Virginia, described below.

Lake Virginia.—The upper end of Lake Virginia (formerly known as Mill Lake), distant about 4 miles from Eastern Passage and about 12 miles from Wrangell, cuts through this belt of marble (No. 50). The rock ranges from grayish-white and coarse-grained marble at the east side of the exposure to fine-grained bluish-gray and veined marble at the west. The fine-grained grayish and banded material predominates. Near the east side, near the contact with granitic intrusive rock, contact minerals of fibrous radial character are developed in the coarse-grained marble.

Three thin sections of marble from this locality were examined by T. N. Dale and G. F. Loughlin.

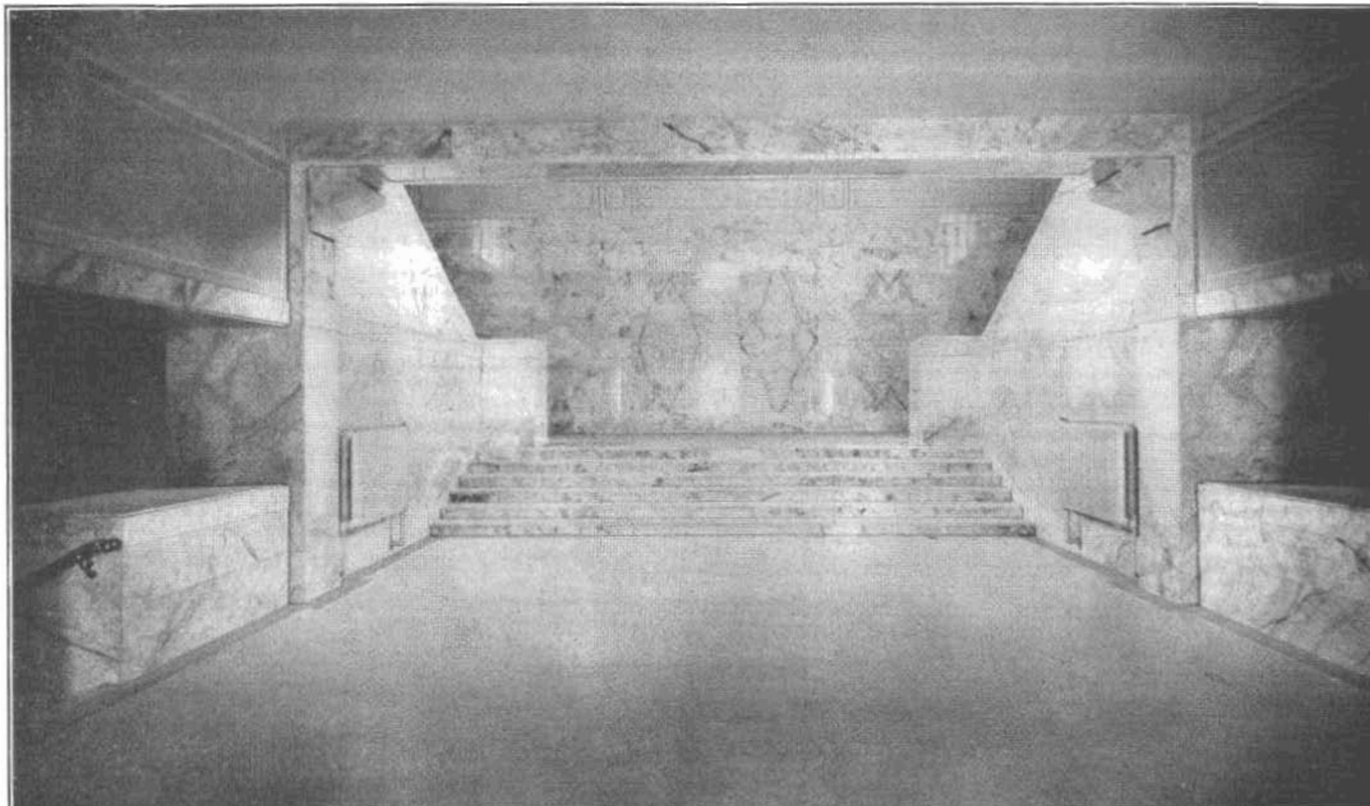
A section of the grayish-white marble showed a very uneven texture, being composed mainly of portions having two grades of fineness. Micrometer measurements of the grain diameter of the finer part showed a range from 0.074 to 0.555 millimeter, with an estimated average of 0.154 millimeter. The coarser part showed a grain diameter from 0.185 to 2 millimeters, mostly 0.37 to 1.1 millimeters, with an estimated average of 0.434 millimeter. A few grains of quartz are present.

A section of the gray marble showed an even texture and a grain diameter ranging from 0.05 to 0.62 millimeter, mostly between 0.125 and 0.375 millimeter, with an estimated average of 0.145 millimeter. According to the Rosiwal measurement the average grain diameter is 0.0054 inch, or 0.137 millimeter.

A section of the coarse-grained, nearly white marble containing a fibrous mineral in large radial aggregates consists largely of talc bands or fibers in extremely thin parallel and divergent aggregates 0.01 to 0.1 millimeter thick, between broader bands of calcite. Considerable carbonate is interleaved with the talc fibers. Here and there large plates of dolomite cross the foliation. Many minute crystals of pyrite rusting to limonite are present. It is suggested by Mr. Loughlin that the talc may have been derived through the complete replacement of tremolite or diopside, or that it may be a primary metamorphic mineral formed under less heat and pressure than required to form tremolite and diopside. Local conditions favor the possibility that the talc is a primary metamorphic mineral.

ENTRANCE TO YEON BUILDING, PORTLAND, OREG., DECORATED WITH TOKEEN MARBLE.

Note the matched panels produced by sawing slabs of clouded marble.



CORRIDOR, UNIVERSITY OF UTAH, SALT LAKE CITY, UTAH, DECORATED WITH TOKEEN MARBLE.

tance into the mountains toward the north-northwest. On the west the bordering rock is schist, and on the east the marble is in contact with an intrusive mass of quartz-bearing basalt. A mass of fine-grained gray granite forms a cliff on Blake Channel about 3 miles west-northwest of this locality. Five claims of 20 acres each

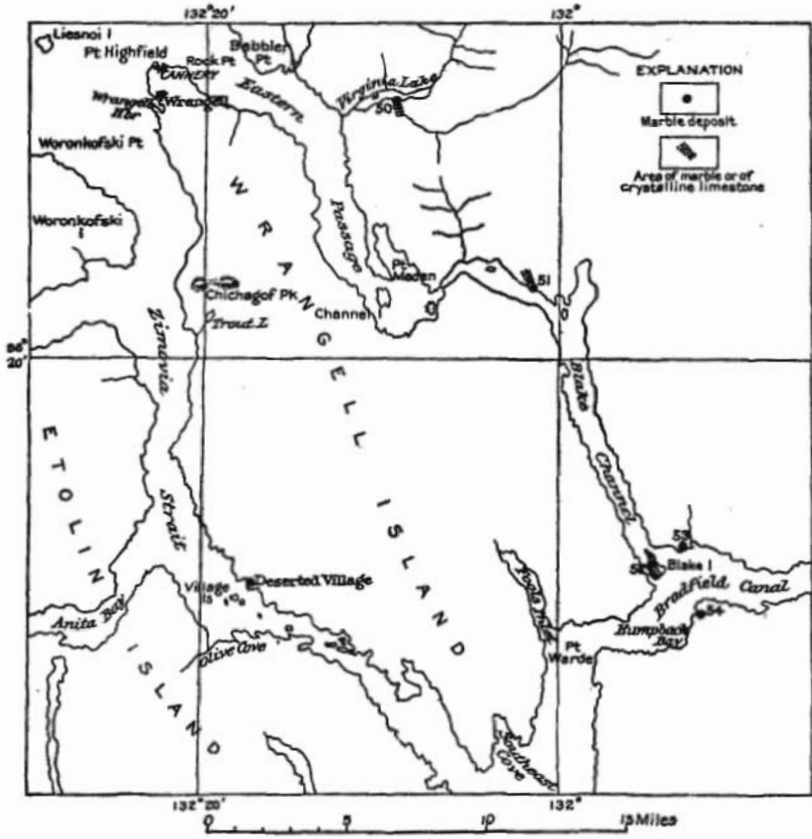


FIGURE 4.—Map showing marble deposits examined on mainland east of Wrangell Island and on Ham Island. From Coast and Geodetic Survey chart 8200.

have been staked on this marble by Frank Spalding, of Wrangell, who has opened several prospects.

BLAKE OR HAM ISLAND.[1]

Ham Island (see fig. 4) lies in Blake Channel at its junction with Bradfield Canal about 25 miles southeast of Wrangell (No. 52). It is about 1¼ miles long and is composed largely of crystalline limestone interstratified with beds of calcareous schist. These beds dip steeply northeast and strike about N. 35° W., falling in line with the

[1] Blake Island by decision of the United States Geographic Board; Ham Island on the Coast Survey chart and in local usage.

long lens or belt of crystalline limestone that crops out on the mainland about 10 miles northwest of Ham Island.

The marble beds have been extensively tested on Ham Island, and deposits have been prospected also on the adjacent mainland east

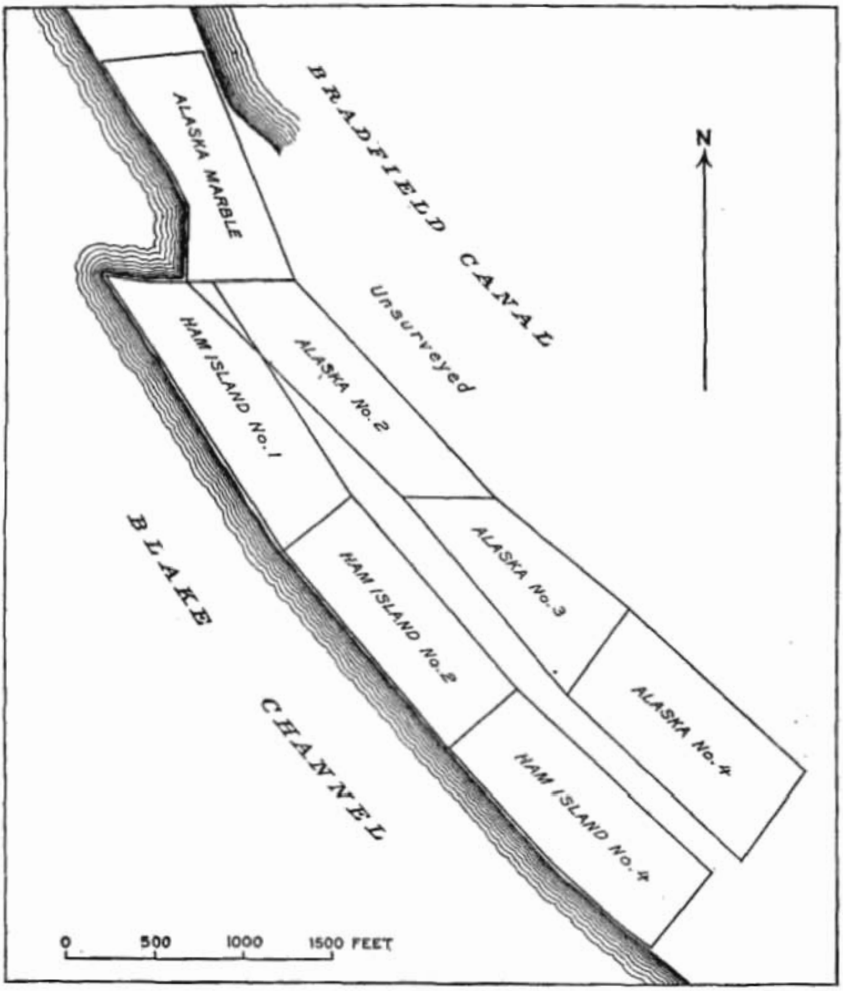
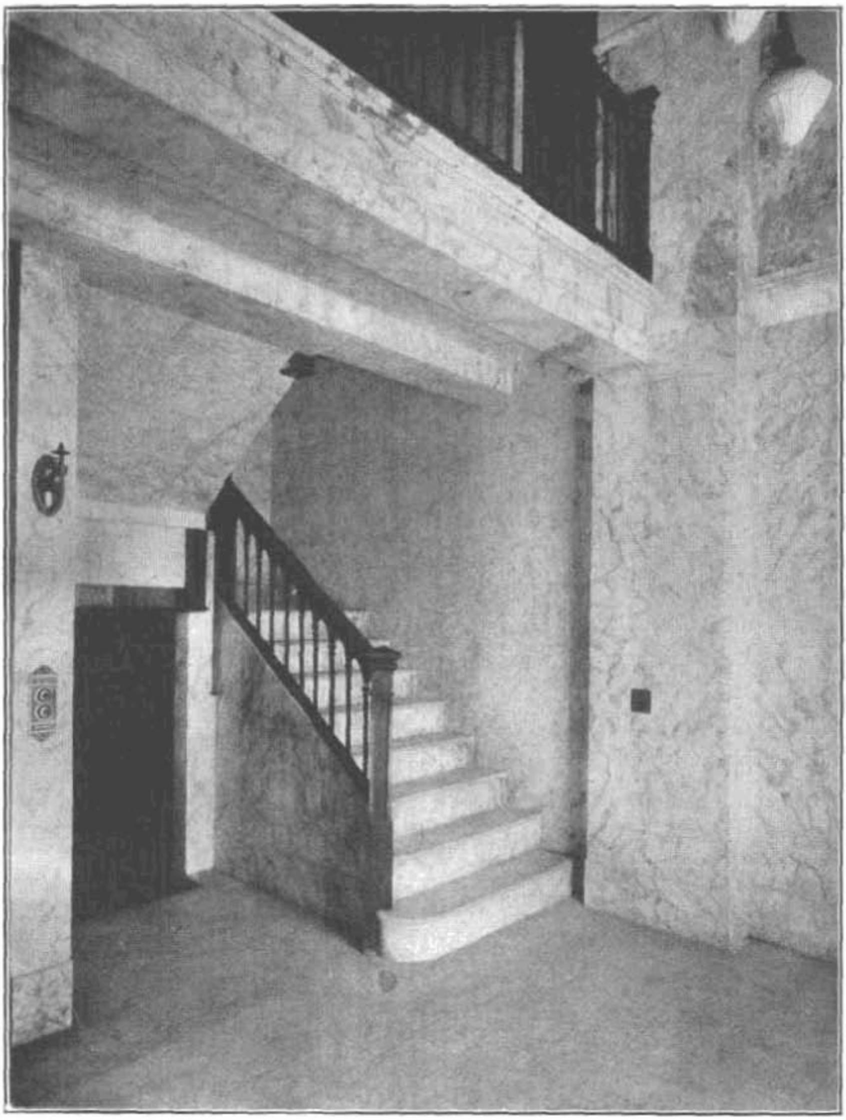
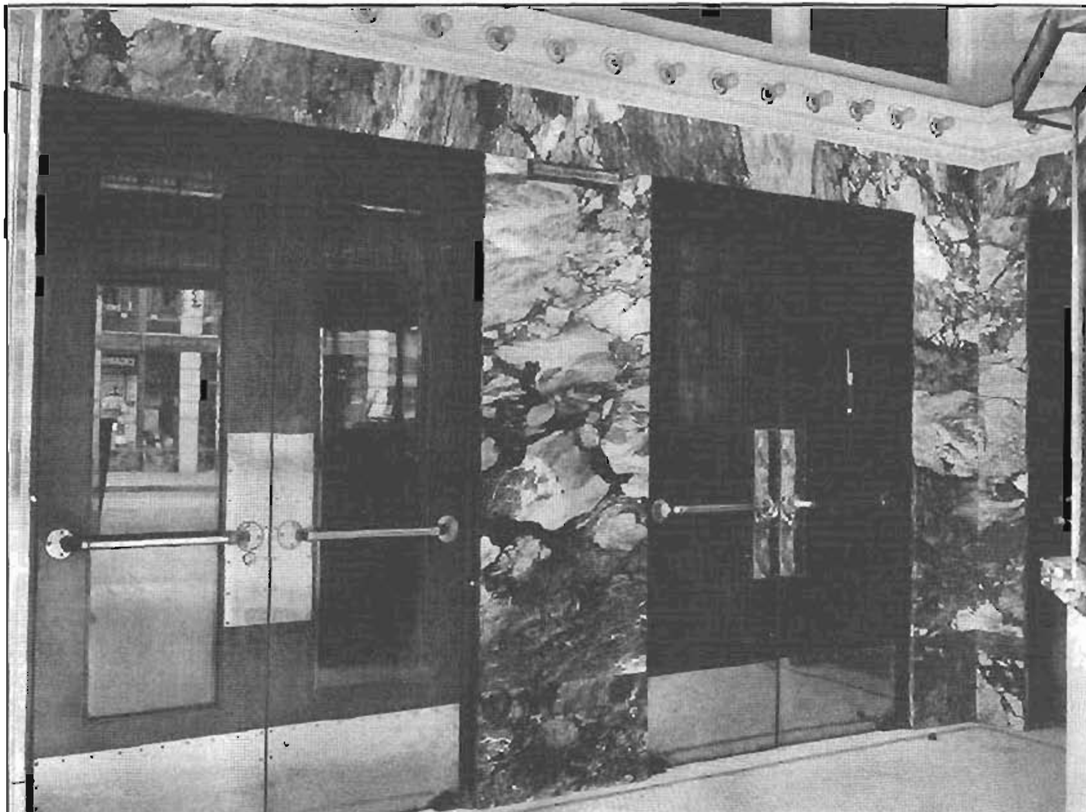


FIGURE 5.—Sketch map showing claims of Vermont Marble Co. on Ham Island.

and southeast of the island, with the result that claims have been located in all these places. In the northern part of Ham Island the greater part of the marble available is coarse grained, and ranges in color from light grayish blue to dark gray; but some of it is nearly white. A little fine-grained marble, mostly white, occurs in the southeastern part of the island. The strata have been crumpled and folded and are slightly schistose in places, but the stone gen-



LOBBY OF ISAACS BUILDING, LOS ANGELES, CALIF.; FLOORS, STAIRS, AND WALLS OF TOKEEN MARBLE.



ENTRANCE TO MAJESTIC THEATER, PORTLAND, OREG., DECORATED WITH COLORED MARBLE FROM DICKMAN BAY.

erally seems sound, and the rock is not so badly checked and fractured as in certain other marble areas in southeastern Alaska. Several systems of joint planes intersect the beds, but the joints are spaced widely enough not to interfere greatly with quarrying. The marble occurs in beds of varying thickness, generally 2 to 4 feet or more, that strike northward and dip at an angle of 50° or more toward the east. In the eastern part of the island, south of the middle, some beds of fine-grained white marble, 20 feet thick, alternating with coarser crystalline marble, have been revealed by the core drill. In some places the presence of many veins and nodules of quartz and chert in the white marble has been shown by drilling perpendicular to the bedding, and it is feared that they may present a serious obstacle to the utilization of these beds. The quartz veins are generally from a fraction of an inch to a few inches in thickness, though at least one vein a foot thick has been noted.

Two groups of claims on Ham Island, owned originally by Woodbridge & Lowery and by Mr. Miller, have been purchased by the Vermont Marble Co. (see fig. 5) and are being thoroughly prospected by that company, but up to 1914 the results had not warranted opening a commercial quarry. Many large blocks of marble were quarried by the former owners, and from these blocks tombstones and small blocks have been cut and polished by hand for local use.

Thin sections of two samples of marble from Ham Island were examined by T. N. Dale. One section of medium-grained grayish-blue marble showed an irregular texture, with grains mostly elongate and much twinned. Graphite is present. Measurements by the micrometer showed a grain diameter ranging from 0.28 to 2.52 millimeters, mostly between 0.84 and 1.68 millimeters. The Rosiwal measurement showed an average diameter of 0.0127 inch, or 0.3235 millimeter. The other section was taken from very coarsely crystalline grayish-white stone and showed a grain diameter ranging from 1.39 to 3.64 millimeters. The other coarse varieties fall between these two grades.

MAINLAND NEAR HAM ISLAND.

On the mainland in the vicinity of Ham Island the Vermont Marble Co. holds two claims of 160 acres each about 1 mile east of Ham Island on the north side of Bradfield Canal (No. 53), and two claims 1½ miles southeast of Ham Island on the south side of Bradfield Canal (No. 54). Neither of these properties had been developed at the time the writer was at Ham Island.

REVILLAGIGEDO ISLAND.

Prospecting for marble on Revillagigedo Island has been carried on at intervals for about 15 years. Little of importance has been done, however, since the survey of the Ketchikan district by the

Wrights,[1] who noted the important features of the marble deposits on this island as follows:

A well-defined limestone belt traverses the eastern portion of Revillagigedo Island in a northwesterly direction and is exposed in Thorne Arm, Carroll Inlet, and George Inlet. Its widest development is on the north side of George Inlet, near the head [No. 55], where marble claims known as the Bawden group were located in 1904. The deposit is included in the crystalline schist near the contact with the less-altered slates to the southwest. The marble beds range from 10 to 20 feet in width and are separated by strata of calcareous schist. Their strike is northwest and their dip northeast. The marble is exposed in

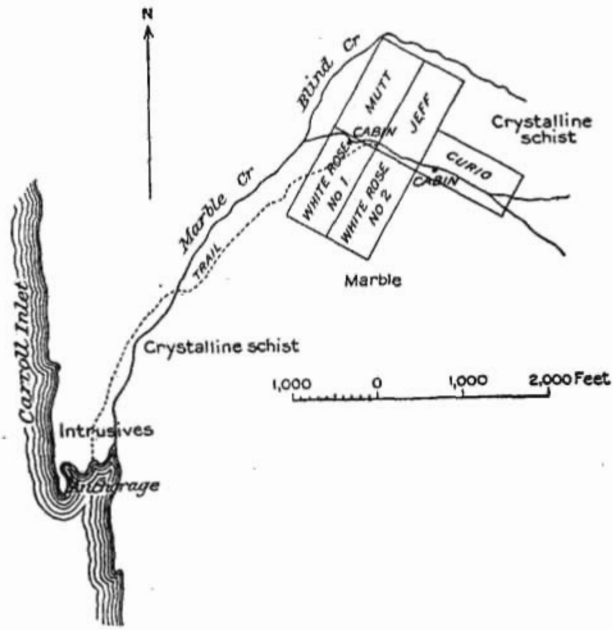


FIGURE 6.—Sketch map of Dickinson & Bell marble claims on Revillagigedo Island near Carroll Inlet.

cliffs near tidewater and is of good quality, being relatively free from fracture and joint cracks, finely crystalline, and from white to gray in color. No large developments have been started on this property.

In Carroll Inlet, to the southeast, claims have also been located on the same belt, but at this locality the deposit is not so extensive as in George Inlet.

In addition to these claims two groups were noted by the writer in October, 1912, on the east side of George Inlet. One (No. 56) lies 7 miles north of the point where George Inlet and Carroll Inlet coalesce, and the other (No. 57) about 6½ miles north of that point. Only the shore exposures were visible at these places, and no prospects could be found. The rock exposed consists of grayish-white to gray fine to medium grained schistose marble, interstratified with and intersected by dikes of mica dacite. Nearly as much dike rock as

[1] Wright, F. E. and C. W., op. cit., pp. 197–198, pl. 2.

marble is exposed on the beach at the southern locality. All the beach exposures of marble are very soft and saccharoidal, almost too soft to yield a hand specimen. The beds dip about 30° a little north of west. So far as these exposures indicate, little if any commercially valuable marble is present at either place.

In the summer of 1915 Theodore Chapin examined certain marble deposits along Carroll Inlet, and his notes given below are descriptive of the most valuable deposit:

A deposit of white marble is being developed near Carroll Inlet by G. E. Dickinson and B. Bell. The claims are on Marble Creek, a stream entering a cove on Carroll Inlet from the east about 10 miles from its head (No. 58). (See fig. 6.) From this cove a trail leads to the claims, a distance of about a mile and a half. The rock is exposed by surface cuts at several places and along Marble Creek for half a mile, the width covered by the claim locations. In this distance the rock shows little variation. It consists of white crystalline marble of even texture and of very fine grain. No analysis was made of the rock, but to judge from its slight effervescence with acid it is probably dolomite.

Timber suitable for cabins and other construction grows on the claims, and water power sufficient for quarrying could be obtained from Marble Creek. The fall of 300 feet between the claims and the beach in a distance of a mile and a half offers no serious difficulty in tram construction.

COMMERCIAL CONSIDERATIONS.

By E. F. Burchard.

FACTORS CONTROLLING VALUE.

The value of a marble deposit in southeastern Alaska can not be judged by small surface samples alone, although tests of such samples may be of considerable significance. The character of the deposit as a whole must be considered, or at least of so much of it as will be required for a quarry, as well as extent, color, lack of objectionable impurities such as silica, pyrite, argillaceous and organic matter, soundness, absence of fractures or joint planes and of intersecting dikes, facility of quarrying and loading on vessels, distance and freight rates to markets, and competition.

The feature that probably will cause the most serious hindrance to profitable quarrying in southeastern Alaska is the fracturing and jointing of the beds. Observations have shown that this condition is very prevalent at the surface in this region, and such quarrying and drilling as has been done has shown that fractures, or "shakes," as they are called locally, extend in places to a depth of at least 100 feet. It is of course possible that at greater depths sounder stone will be found, but it is not profitable to be obliged to reject a large percentage of waste simply because the quantity of available blocks of the requisite size is limited by the structure of the deposit. The heavy rainfall and the influence of the dense vegetation in this region have softened the surface marble, in places, to surprising depths compared with those noted in well-known marble regions in the United States.

The practical judgment of a competent marble quarryman is necessary to decide many of the questions relating to the availability of the stone. Cross trenching, a common form of prospecting to determine the surface extent of a marble deposit, must be supplemented in southeastern Alaska by the core drill. A careful study should be made at the surface of the directions or strikes of the several systems of joints, their minimum, maximum, and average spacing, the direction and angle of their dip, and the nature of the fracturing that is not related to the systematic jointing. A sufficient number of holes should then be drilled to such depth and in such direction that a definite idea may be obtained as to the character of the beds below the surface, especially in relation to fracturing and jointing and the hardness of the marble.

Tests of the cores, including chemical analyses, measurement of size of grain, absorption, porosity, compressive strength, and polish, are all of great value, but satisfactory tests for strength and polish may not be practicable unless the core is 2 inches or more in diameter.

PROSPECTING.

Important technical details of modern prospecting of marble deposits have been recently published in a paper by Bowles,[1] in which the following suggestions are given in much greater detail.

Value of geologic maps.—Some marble beds crop out in long, narrow bands, which may extend for many miles. These bands represent truncated edges of folded strata and they may be curved or straight, their form depending on the topography and on the nature of the folds. Other marble beds have irregular outlines owing to faulting or to incomplete metamorphism of the original limestone mass. Much of the rock surface may be covered with gravel, sand, or clay to a considerable depth. The geologist may, by a careful study of outcrops exposed here and there, obtain a knowledge of the chief structural features and may thus determine the position, attitude, and thickness of the marble beds with a fair degree of accuracy, even if they are almost entirely hidden by surface débris. If geologic maps of marble areas are carefully made they are of inestimable value to the marble prospector. By accurately locating himself in the field and carefully studying a geologic map the prospector may determine the position of the marble beds beneath the surface and

[1] Bowles, Oliver, The technology of marble quarrying: Bur. Mines Bull. 106, pp. 39–46, 1916.

know something of their extent and attitude, although the beds are unseen. It is important, therefore, that all available geologic maps of the region be consulted freely.

Detailed prospecting.—Knowledge of the suitability of any particular site can be gained only by detailed prospecting, including determinations of the depth of overburden and of surface decay of the rock and of the extent, quality, impurities, and soundness of the deposit. It is unwise to proceed with development work without reasonable assurance that an available mass of sound and attractive marble is sufficiently uniform in quality and abundant in quantity for profitable exploitation.

Determination of overburden.—The depth of stripping necessary may be determined at small cost by putting down drill holes. Such preliminary tests may save much wasteful expenditure, for in places stripping has been attempted without any previous investigation of the depth of soil to be removed, and great loss has resulted from thus working blindly.

In estimating the necessary cost of stripping for a new quarry the attitude of the marble beds must be taken into account. If the beds are flat a greater area of rock must be uncovered than if they are steeply inclined or vertical.

Conditions relating to disposal of strippings are of great importance. In certain places it is a matter of some difficulty to find a suitable place in which to deposit the soil that must be removed; in other places the soil may be carried to neighboring valleys or low-lying areas and usefully employed.

Surface study.—Surface observations of the marble beds are of great value, especially as regards jointing. The process of weathering tends to emphasize all unsoundness and thus facilitates the study of joint systems. Exposed surfaces may also permit a determination of dip and strike and the thickness of the beds. In determining the quality of a marble deposit a study of uncovered knobs or ledges should not, however, be deemed sufficient. On account of surface weathering the top rock may differ materially from the deeper parts of the deposit. Moreover, the number and spacing of joints at the surface may be no indication of the prevailing conditions at depth. In order to obtain a fair idea of the quality and soundness of the marble and the supply available, drill cores should be taken at several points.

Diamond-drill prospecting.—The ordinary diamond drill will give the necessary information regarding color, uniformity, and general appearance of the stone, and also the extent of the formation. It will not, however, give definite information concerning the dip and the strike or the unsoundness of the marble. If drill cores come out in long, unbroken sections that show no indication of cracks, it may be assumed that the rock is fairly sound. If, on the other hand, the core is in short sections, the rotation of the drill will as a rule have so worn and rounded the broken ends that it will be impossible to determine whether the breaks are due to natural planes of weakness in the rocks or to the process of drilling itself.

A method of prospect drilling that has been employed involves the use of the double-core barrel drill, consisting of an outer and an inner tube, which was designed primarily for drilling bituminous coal and operates in such a manner as to bring out a core from delicate material with a minimum of breaking or other damage.

The use of such a drill enables the prospector to judge the unsoundness of the marble at points beneath the surface, for by examination of the ends of the sections of drill core he can generally interpret the breaks and state whether they are due to natural joint planes in the rock or to the process of drilling. If the cores are properly oriented, the proximity and direction of all natural cracks in the rock and in the immediate vicinity of the drill holes may thus be ascertained. If the marble deposit is well exposed, the dip and the strike may be determined from examination of the outcrops. If, however, it is completely buried, these features may be determined from the drill cores if they are carefully oriented.

Information should be obtained with a minimum number of drill holes. In this respect prospecting for marble differs materially from prospecting for metalliferous ores, as the soundness of the ore is not important, whereas with the marble every crack or cavity increases the proportion of waste in the quarried product. A drill hole in a quarry may be nearly as objectionable as a crack. If the deposit lies flat or nearly so, a single well-placed core driven entirely through the deposit will give information as to the character of the marble and show whether it is one homogeneous mass or is divided by streaks of color or open beds into different layers and whether the layers differ in character. If, however, the deposit dips at a moderate angle and is comparatively thick, the best way to determine its thickness and the character of its beds is to lay out a line of drill holes at right angles to the strike. The first drill hole that penetrates the upper beds should begin in the hanging wall, the bed immediately overlying the marble bed. The holes should be of such depth and spacing that the bottom of a hole in the upper beds will penetrate the same layer as the top of the neighboring hole on the side toward the footwall. The core nearest the footwall should reach and penetrate this wall. By this method a series of core holes of moderate depth will supply samples from all the beds, and the relatively high cost of drilling deep holes penetrating the entire deposit will be avoided.

A marble deposit in which the color, texture, or other qualities are highly satisfactory may nevertheless not warrant commercial development because of joints and cracks. Most joints occur in two systems, the openings in each system being approximately parallel with one another and the two systems being more or less nearly at right angles. In Alaskan deposits generally more than two systems are present. The spacing of the cracks varies widely in different deposits and even in different parts of the same deposit. In many places cracks persist to almost any depth to which quarrying operations have been carried. It is important to determine, if possible, which of the cracks that appear at the surface are likely to persist, and also their nature and spacing in the deeper parts of the deposit. Where the cracks are nearly vertical a vertical core taken out of marble that is unsound may reveal the presence of only a few of the cracks. There, under such conditions, a vertical hole is not reliable as a means of estimating the unsoundness to be encountered.

It is practically impossible to take out good cores that are representative of the deposit from horizontal drill holes. The core from a horizontal hole invariably breaks into short pieces, which grind on each other, in spite of the use of the double-core barrel. Therefore, if the marble beds lie flat, or nearly so, unsoundness must be prospected for by inclined core holes; otherwise the cores will not yield the information desired. If the marble deposit stands at a high angle, one set of core holes driven in an inclined direction and penetrating from the hanging wall to the footwall, or the reverse, can be laid out so as to give the information required as to the quality of the stone and also the unsoundness. It is important to take cores near the top, near the middle, and near the bottom of the deposit, because the unsoundness may vary in different beds, as well as in different parts of the same bed.

In order to get the fullest information from an inclined core hole the core parts should be matched up from one end to the other and placed as fast as obtained on an inclined rack that will hold the core in a position parallel with the hole from which it was taken. While the core is in this position the compass bearing of the cracks and also the angle that they make with the core can easily be determined. From this information a plan may be made from which the probable percentage of marble unaffected by unsoundness may be computed with reasonable accuracy.

As a rule, drill cores are not preserved with sufficient care by quarrymen. They are often carelessly stored, lost, or given away as samples. It is important that every part of every drill core be carefully marked and stored for future reference. It must not be assumed that the value of drill cores disappears after their first investigation. They are invaluable records, which should be available at all times.

All drill cores should be polished on one side, in order to facilitate determination of color, uniformity, and degree of polish that may be obtained. It is well to supplement the evidence of the cores by stripping the marble along each line of holes, and also to dig a trench or two at right angles to each line of core holes, so as to expose the marble to some extent along the strike.

THE PROBLEM OF WASTE.

As the problem of waste is one of the most important to be considered in connection with the marble industry in southeastern Alaska, it seems fitting to refer here to certain principles discussed in the recent publication by Bowles,[1] who has made a study of marble quarrying with special reference to safety, efficiency of operation, and prevention of waste.

The problem of waste is twofold. In the first place it has to do with improved equipment and modern methods of excavation which tend to keep the proportion of waste at a minimum; and in the second place it deals with the various uses to which waste material may be applied. In other words, it is a problem, first, of waste elimination and, second, of the utilization of whatever waste is unavoidable.

Waste elimination is much more desirable than waste utilization. Methods that result in excessive waste should not be countenanced merely because an outlet has been found for waste material in the form of by-products. As a rule the cash return from quarry by-products is only a fraction of the production cost of the waste material from which they are supplied. As an illustration, it may be assumed that a moderate cost of marble excavation (in 1915) is 25 cents a cubic foot, or $3 a ton. A fair price for riprap is 50 cents a ton, one-sixth of the cost of excavation. The quarryman seeks a market for riprap, not because the production of riprap is profitable, but for the reason that he prefers to obtain one-sixth of the cost of his waste material rather than to receive nothing at all. By eliminating a ton of waste he saves $3, whereas by marketing it he saves only 50 cents.

WASTE ELIMINATION.

The loss of a part of the good stone is unavoidable. Channeling, drilling, scabbing, sawing, and coping are all necessary operations which use up an appreciable share of the stone. In addition to losses due to the processes of manufacture, more or less stone must be thrown away on account of imperfections. It is, however, the throwing away of masses containing many cubic feet of good stone, or the handling

[1] Bowles, Oliver, op. cit., pp. 108–120.

of an excessive amount of inferior material, which constitutes the serious and, for the most part, avoidable losses.

The natural imperfections in marble that constitute the source of the greater losses are unsoundness, strain breaks, impurities, and lack of uniformity either in color or texture.

Systematic prospecting is a first step toward waste elimination. Before operations are started the outcrop or stripped surface should be mapped carefully to show the direction of strike and dip and the directions of the chief joint systems. Naturally the quarry walls should parallel those rock structures that are most pronounced. If the beds are tilted and if inferior beds alternate with those of good quality, it may seem advisable to make the quarry walls parallel the strike and dip. If the rock is of uniform quality but intersected by prominent joint systems, the quarry walls should be parallel and at right angles to the chief joints, or possibly the contiguous walls should parallel the two chief systems of joints if these should meet at oblique angles. Careful mathematical calculations may be necessary before it can be determined definitely which plan will give the minimum of waste. If a mistake has been made in the original plan of quarrying, it is possible to change the plan and quarry parallel with the chief rock structures. By such a change, however, corners are left and the original floor space greatly reduced.

The depth of inferior rock due to surface alteration is an important consideration. Although the actual value of the untouched material may be negligible, the cost of handling great quantities of waste material adds greatly to the expense of quarrying. The removal of such material may, under certain conditions, be avoided by driving tunnels.

If the tunnel is driven in good marble a large quantity of good material is thus destroyed. If practicable, the opening should be driven in an inferior bed. The blasting required in tunnel work demands care to avoid shattering the good marble.

A condition of strain within the marble mass has in certain places caused so great a proportion of waste that the workings have been abandoned. The rock is under a severe compressive stress usually in one direction only. Quarrying relieves the stress at certain points, and the consequent expansion may cause fracturing. Furthermore, the expansion of one mass that is still in rigid connection with the main mass still under compression may cause irregular or oblique fractures to form between the two masses. In order to avoid the waste due to this cause relief should be afforded by uniform expansion of as large a mass as possible at one time. To this end a line of closely spaced deep holes should be drilled along each side of the quarry parallel with the direction of compression, with a similar line of holes across the quarry at right angles to the first line. The rock will expand and close the holes in the latter line, and the strain will thereby gain relief. For a complete discussion of the problem of strain breaks the reader is referred to pages 123–145 of Bureau of Mines Bulletin 106.

Unsoundness is the most prolific source of waste, and the one that is receiving least attention in the majority of American marble quarries. Too great emphasis, therefore, can not be placed on this phase of the waste problem. Channeling regardless of unsoundness probably accounts for the loss of a greater quantity of good marble than any other single cause. Waste results wherever joints pass through blocks, and the waste becomes excessive when they pass obliquely. A reduction to a minimum of this form of waste involves first a modification of channeling and drilling directions in order that they may conform with the directions of the chief joint systems, and second a variation in the spacing of cuts to make them coincide with joints and thus eliminate the joints from the blocks.

In addition to the sources of waste discussed above, Bowles takes up in turn waste due to lack of uniformity, to irregular blocks, to impurities, to bad color, and to strain breaks in quarrying, and makes practical suggestions for overcoming to a large extent the influence of these disadvantages. He points out, for instance, that in quarrying marble varying in color or texture an endeavor should be made so to quarry as to produce material that can be closely classified, by drilling, channeling, and cross breaking, as nearly as possible along boundaries between different grades of material. In treating of waste due to irregular blocks he has sketched the various forms of irregular blocks as quarried, outlined the circumstances under which they are produced, and showed the necessity for taking into consideration the prevailing rock structure in laying out the quarry and in cutting out the blocks of marble. If the marble is sound right-angled blocks are doubtless the most economical, but in quarrying unsound or nonuniform material conformity with structure may demand that the block be acute-angled, and obviously this is the most economical form to produce under such circumstances. Bowles also points out that the nature of the product has an important bearing on the matter of waste, and that if the blocks are entirely cut into thin stock there should be relatively little waste from inclined blocks. He has summarized certain rules governing the shape of blocks as follows:

1. Effort should be made to produce right-angled blocks, unless there is a valid reason for doing otherwise.

2. Quarrying on a level floor and splitting diagonally to form monoclinic blocks may be justified where much thin stock is produced. If much cubic stock is desired, the quarryman should consider carefully the advisability of channeling on an inclined floor in order to produce right-angled blocks.

3. A direction of channeling that results in inclined beds separated by open bedding seams pitching into the corner of a quarry should by all means be avoided. The same is true of inclined beds that are not separated by open seams but have a decided rift or color distribution parallel with the bedding.

4. As regards unsound or nonuniform material, although an effort should be made to avoid oblique angles, conformity of cuts with structure is, as a rule, more economical than right-angled cuts.

With regard to the avoidance of waste due to impurities, such as silica, dolomite, pyrite, and mica, the chief advice given by Bowles is to avoid so far as possible the quarrying of marble beds containing these minerals, especially if the material is to be used for exterior work.

WASTE UTILIZATION.

Although the proportion of waste may be kept at a minimum by the adoption of economical quarry methods and efficient machinery, there is always more or less unavoidable waste. The second phase of the problem of rock waste therefore is concerned with utilizing the waste material. Many manufacturers have found that the manufacture and sale of by-products from otherwise waste materials have placed their industries on a profitable basis. There are various difficulties in the way of developing waste utilization so far as most marble deposits in Alaska are concerned. The lack of a local market for rock products hinders activity. Freight rates to possible markets may be excessive.

Among the important uses that have been suggested for waste marble that might be applicable in Alaska and on the Pacific coast are in riprap, for shore protection; for road material; for burning into lime; for use in a pulverized form for improvement of soils; and for smelter flux.

LOCAL SAWING PLANTS.

Thus far the products of Alaska marble quarries have been confined practically to marble for interior finishing (see "Uses," p. 110), and the percentage of waste in quarrying is necessarily great, because it does not pay to ship blocks that can not be almost entirely sawed into large and perfect slabs for polishing. Much of the marble appears to be of suitable character for exterior construction and local sawing plants might produce much dimension marble from blocks of such stone that would otherwise be rejected. Small polishing plants might also utilize much of the waste marble by working it up into the smaller slabs required for base boards, tiles, plumbing fixtures, moldings, and the like. A small sawing plant was installed at one quarry in southeastern Alaska, but operations were soon discontinued and no figures are available as to the relative costs of operation there and on Puget Sound; it is understood, however, that the high cost of coal in this part of Alaska makes manufacturing generally rather expensive. Moreover, the Puget Sound cities are supplied with relatively cheap electric power.

WATER POWER AND ELECTRICITY.

In southeastern Alaska, according to Canfield,[1] water power has been developed at 15 or more places, aggregating 35,100 horsepower. It is reported that abundant water power is available on Kosciusko Island, near Holbrook, less than 4 miles from the marble quarries on Marble Island. To deliver electric power to Marble and Orr islands a cable would have to be laid across a channel measuring, according to the Coast and Geodetic Survey charts, about 3,400 feet in width and 120 feet in depth; or else a line several miles longer would have to be built around the head of Tokeen Bay. In the southeastern part of Prince of Wales Island and on Revillagigedo Island the appearance of certain mountain streams and waterfalls suggests the possibility of power not yet utilized. It should be stated, however, that none of these streams have been studied by the writer with reference to their source of supply, and that unless fed from natural reservoirs such streams can not be relied on to furnish power throughout the year.

A systematic investigation was begun by the Geological Survey in cooperation with the Forest Service in the spring of 1915, to determine the location and the feasibility of water-power sites in southeastern Alaska, for it was realized that lack of definite information in regard to the quantity of water available and other physical factors that determine the feasibility of a power site has been one of the principal impediments to development. From the preliminary report[2] on these investigations the following data are quoted which appear to be of interest in connection with the possible development of marble deposits:

In the summer of 1914 Leonard Lundgren, central district engineer of the Forest Service, made a reconnaissance of water-power sites in southeastern Alaska to determine the possibility of establishing the pulp industry in the Tongass National Forest, which covers a large part of southeastern Alaska. In connection with this reconnaissance a census of water powers was taken (see following table), which has been revised by Mr. Lundgren to January 1, 1916, and is here published by courtesy of the Forester.

[1] Canfield, G. H., Water-power investigations in southeastern Alaska: U. S. Geol. Survey Bull. 642, p. 106, 1916.

[2] Idem, pp. 105–108.

Developed water powers in southeastern Alaska January 1, 1916, in horsepower.

[Prepared by Leonard Lundgren, district engineer, U. S. Forest Service.]

Ketchikan region:			
Citizens Light, Power & Water Co.		2,000	
New England Fish Co.		2,200	
Miscellaneous plants		1,000	
			5,200
Wrangell region			0
Sitka region:			
Sitka Wharf & Power Co.		350	
Chichagof Mining Co.		500	
Miscellaneous plants		150	
			1,000
Juneau region:			
Alaska-Treadwell Mining Co.:			
Douglas Island plant	4,000		
Sheep Creek plant	4,100		
Nugget Creek plant	5,700		
		13,800	
Alaska-Gastineau Mining Co.:			
Salmon Creek plant, No. 1	4,000		
Salmon Creek plant, No. 2	4,000		
Annex Creek plant	5,000		
		13,000	
Alaska Electric Light & Power Co.		1,000	
Miscellaneous plants		1,000	
			28,800
Skagway region			100
			35,100

During the last few years some large water-power plants have been installed near Juneau to supply power for mining, and attention has been called to the feasibility of improving other power sites in that region and elsewhere in southeastern Alaska, to meet the increasing demand for power to be used in mining, lumbering, and fisheries, and the possible future demand for its use in the manufacture of wood pulp and electrochemical products. The streams on which it is possible to develop power and the bays or other water bodies into which these streams discharge are listed in the following table:

Streams affording power sites in southeastern Alaska, with position or water bodies into which they flow.

Mainland.

Porcupine River, near Porcupine.[1]
Endicott River, west coast of Lynn Canal.
Cowie and Davies creeks, Berners Bay.
Lemon Creek, near Juneau.[2]
Carlson Creek, Taku Inlet.[3]
Turner Lake outlet, Taku Inlet.[4]

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[1] Gaging station maintained in 1909 by Porcupine Gold Mining Co.
[2] Gaging station being maintained by mining company of Juneau.
[3] Gaging station being maintained by Alaska-Gastineau Mining Co., of Juneau.
[4] Gaging station maintained in 1908 and 1909 by Alaska-Treadwell Gold Mining Co.

Speel River, Speel River project, Port Snettisham.
Grindstone Creek, north shore of Stephens Passage.
Rhein Creek, north shore of Stephens Passage.
Long Lake outlet, Speel River project, Port Snettisham.[1]
Crater Lake outlet, Speel River project, Port Snettisham.[1]
Tease Lake outlet, Speel River project, Port Snettisham.
Sweetheart Falls Creek, south arm of Port Snettisham.[2]
Port Houghton, Stephens Passage.
Farragut Bay, Frederick Sound.
Mill Creek, near Wrangell.[2]
Bradfield Canal, upper end of Cleveland Peninsula.
Smugglers Cove, southeast shore of Cleveland Peninsula.
Helm Bay, southeast shore of Cleveland Peninsula.
Shelockham Lake outlet, Bailey Bay.[2]
Chickamin River, east shore of Behm Canal.
Rudyerd Bay, east shore of Behm Canal.

Baranof Island.

Port Conclusion, southeast coast.
Patterson Bay, east coast.
Red Bluff Bay, east coast.
Cascade Bay, east coast.
Baranof Lake outlet, Warm Spring Bay, east coast.[2]
Kasnyku Bay, east coast.
Green Lake outlet, Silver Bay, west coast.[2]
Necker Bay, west coast.
Deep or Redoubt Lake, west coast.

Chichagof Island.

Slocum Arm, west coast.
Suloia Bay, Peril Strait.
Khaz Bay, west coast.
Freshwater Bay, east coast.
Sitkoh Bay, southeast coast.
Basket Bay, southeast coast.

Admiralty Island.

Kootznahoo Inlet, west coast.
Hood Bay, west coast.

Kosciusko Island.

Davidson Inlet.

Prince of Wales Island.

Karta River, Karta Bay.[2]
Whale Passage, behind Thorne Island, northeast coast.
Myrtle Lake outlet, near Niblack post office.
Reynolds Creek, near Coppermount.

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[1] Gaging station maintained since January, 1913, by the Speel River project of Juneau.
[2] Gaging station maintained by U. S. Geological Survey.

Revillagigedo Island.

Orchard Lake outlet, at Shrimp Bay.[1]
Beaver Falls, George Inlet.
White River, George Inlet.
Creek, east shore near head of Carroll Inlet.
Fish Creek, Thorne Arm.[1]
Gokatchin Creek, Thorne Arm.
Ketchikan Creek, at Ketchikan.[1]

Annette Island.

Tamgas Harbor.

TRANSPORTATION.

All the marble properties in southeastern Alaska thus far developed and a great many undeveloped deposits are situated either close to or directly on deep water. At present marble in rough blocks is carried by freight steamers to Tacoma, Portland, and San Francisco. Freight rates have been much reduced in the last few years through competition and are reported to be moderate at present.

COMPETITION.

Considerable marble is still shipped to the Pacific coast from quarries in the eastern United States, mainly Vermont and Tennessee, and some is imported from Italy. The output of Alaska marble is increasing, however, and there is said to be a market for all of it that can be produced. In the western half of the United States marble quarries and prospects have been opened in Stevens County, Wash.; Josephine County, Oreg.; Inyo and Tuolumne counties, Calif.; Cochise County, Ariz.; Otero County, N. Mex.; White Pine County, Nev.; Beaver County, Utah; and Gunnison County, Colo. Only the product of the California and Colorado quarries has been of commercial importance thus for.

In British Columbia large deposits of marble are known along the sounds, on the coast, and in the interior. Among those on Vancouver Island are deposits on Nootka Sound and at Beaver Cove. The deposit on Nootka Sound was once quarried but is reported not to have been operated since 1909. On Malaspina Inlet two small deposits have been noted, one of which is of white marble and the other of gray and white marble, mixed with serpentine. The principal marble quarry in the Province is that of the Canadian Marble & Granite Co., on the Canadian Pacific Railway between Lardo and Trout Lake. This quarry is equipped with finishing works and

[1] Gaging station maintained by U. S. Geological Survey.

supplies the greater part of the marble used in British Columbia. White marble is reported near the town of Wycliffe, on the Kimberly branch of the Canadian Pacific Railway, and dolomitic marble of various colors in the Rocky Mountain region on the slopes of Mount Ogden, 2 miles from the mouth of Yoho River.

It is not likely that during the maintenance of the present tariff on marble much of the Canadian product can be sold profitably within the United States, nor can the Alaskan product be delivered in Canada, although it must pass through Canadian waters on the way to the United States.

PRODUCTION.

According to the Survey records the first marble produced in Alaska was quarried in 1901 by the Alaska Marble Co. at Calder, and the first shipment to the United States was made in 1902. For the years 1902 and 1903 no production was reported, but beginning with 1904 the output has steadily increased year by year. It is not possible to give the statistics of production by years, for in only one year were there more than two reporting producers, and it is the custom of the United States Geological Survey to avoid publishing figures that might reveal individual operations. In all, however, from 1901 to 1919 Alaska producers have reported total shipments of unfinished marble to the United States of an approximate value of $1,830,000. Not included in this total is a small output of marble used locally for tombstones and monuments.

USES OF ALASKA MARBLE.

Small quantities of marble have been shipped to the United States from the quarries of the Alaska, El Capitan, Mission, and Alaska-Shamrock companies, but by far the greater part of the output has come thus far from the quarry of the Vermont Marble Co. on Marble Island. The product of this quarry is shipped to the electrically driven mill owned by the company at Tacoma, Wash., where the rough blocks are sawed into smaller blocks for turning and planing and into slabs three-quarters of an inch to 1 inch thick for polishing. The slabs and sawed blocks are worked up into wainscotings, ceilings, floor tiles, moldings, fixtures, rails, balustrades, and a variety of forms for interior finish and decoration. The market for these products is principally in the cities of the Pacific Coast States, but it extends as far eastward as the Atlantic seaboard.

In the important buildings listed below (to 1916) marble from Tokeen, Alaska, is reported to have been used in interior work. (See Pls. XXIII–XXV.)

SEATTLE, WASH.

Arctic Club.
Hoge Building.
Lyons Building.
Haight Building.
L. C. Smith Building.
Bank of California Building.
McCormick Hotel.
King County courthouse.

TACOMA, WASH.

National Realty Building.
Perkins Building.
Tacoma Building.

BELLINGHAM, WASH.

United States post office.

NORTH YAKIMA, WASH.

United States Post Office.

WALLA WALLA, WASH.

Walla Walla County Courthouse.

VANCOUVER, B. C.

Pacific Building.
Rogers Building.

VICTORIA, B. C.

Sayward Building.

PORTLAND, OREG.

Spaulding Building.
Wilcox Building.
Yeon Building.
Selling Building.
Littman-Wolfe Building.
Oregon Journal Building.
Multnomah Building.
Stevens Building.

THE DALLES, OREG.

The Dalles County Courthouse.

SAN FRANCISCO, CALIF.

Flatiron Building.
Odd Fellows Building.
Sharon Estate Building.
Hobart Building.

OAKLAND, CALIF.

Federal Realty Building.
Bankers Investment Building.
Realty Syndicate Building.
Oakland Manual Training School.
Harrison Hotel and Apartments.

SACRAMENTO, CALIF.

Capital National Bank Building.
Forum Building.
Travelers Hotel.

FRESNO, CALIF.

Griffith McKenzie Building.
Rowell Building.

LOS ANGELES, CALIF.

Black Building.
Los Angeles Investment Building.
Title Insurance and Trust Building.
Van Nuys Building.
Brockman Building.
Community Mausoleum, Inglewood.
Haas Building.
Hollingworth Building.
Merchants National Bank Building.
Marsh-Strong Building.
Southern Pacific Passenger Station.

SAN DIEGO, CALIF.

Central Mortgage Building.
Spreckels Theater.
United States Post Office.

SANTA ROSA, CALIF.

Community Mausoleum.

PRESIDIO, CALIF.

United States General Hospital.

MODESTO, CALIF.

Community Mausoleum.

HONOLULU, HAWAII.

Pearl Harbor Naval Hospital.

BOISE, IDAHO.

State Capitol.
Gem Building.

ally of medium grain, and on Gotsongni Bay (No. 46) there are deposits of medium-grained white, pink and white, and bluish-white and gray marble of good quality. Both of these areas are said to be located favorably for quarrying and shipping.

On the mainland east of Wrangell Island occur some areas of medium to coarse grained white to gray and blue marble that may prove of value. Among them might be mentioned that on Blake Channel near its junction with Eastern Passage (No. 51).

White fine-grained marble of even texture, fairly well situated for quarrying and shipping, occurs on Revillagigedo Island near Carroll Inlet (No. 58).

As to the other undeveloped deposits described in this report less encouragement can be given regarding the possibilities of profitable exploitation under present conditions. For special decorative purposes, where cost is a minor consideration, some very unusually banded marble may be obtained from the schistose deposits on Admiralty Island near Point Hepburn (No. 14) and north of Marble Cove (Nos. 15 and 16), but it is doubtful whether these deposits can be quarried in competition with the more homogeneous calcite marbles already developed. About the shores and islands of Glacier Bay (Nos. 2 to 8) there are indications of an abundance of marble, but it is probable that the remoteness of this bay from settlements, the scarcity of large timber in the vicinity, and the uncertainties of navigation will retard active quarrying there.

PATENT TO MARBLE LANDS.

Government lands that are chiefly valuable for their content of building stone (including marble) may be located as placer claims, and but one discovery of mineral is required to support a placer location. An individual may claim 20 acres, but in Alaska no association placer claim located after August 1, 1912, can exceed 40 acres, irrespective of the number of persons associated together. On every placer-mining claim located in Alaska after August 1, 1912, and until patent therefor has been issued, not less than $100 worth of labor must be performed on improvements made during each year, including the year of location, for each 20 acres or excess fraction thereof included in the claim. The proof of improvements must show that their value is not less than $500 and that they were made by the applicant for patent or his grantors. This proof should consist of the affidavit of two or more disinterested witnesses.

The procedure to obtain patent to mineral lands is given in detail in a publication by the General Land Office, Department of the Interior, to which the interested reader is referred.[1]

[1] United States mining laws and regulations thereunder: General Land Office Circ. 430, 104 pp., 1915.

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